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Geochemical Exploration for Gold

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MINES AND MINERALS DIVISION

ONTARIO GEOLOGICAL SURVEY

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Geochemical Exploration For Gold

by

I. Nichol and G.S. Shelp

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Ontario Geological Survey

ONTARIO GEOSCIENCE RESEARCH GRANT FUND

Final Research Report

Foreword

This publication is a final report of a research project that was funded under the Ontario Geoscience Research Grant Program. A requirement of the Program is that recipients are to submit final reports within six months after termination of funding.

A final report is designed as a comprehensive summary stating the findings obtained during the tenure of the grant, together with supporting data. It may consist, in part, of reprints or preprints of publications and copies of addresses given at scientific meetings.

It is not the intent of the Ontario Geological Survey to formally publish the final reports for wide distribution, but rather to encourage the recipients of grants to seek publication in appropriate scientific journals whenever possible. The Survey, however, also has an obligation to ensure that the results of the research are made available to the public at an early date. Although final reports are the property of the applicants and the sponsoring agencies, they may also be placed on open file. This report is intended to meet this obligation.

No attempt has been made to edit the report, the content of which is entirely the responsibility of the author(s).

V.G. Milne
Director
Ontario Geological Survey

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ABSTRACT

The investigation has been concerned with an examination of the nature of gold distribution in glacial till associated with a number of gold deposits. The objective of the study was to assess the reliability of currently adopted procedures and hopefully identify ways by which exploration reliability may be increased. A number of problems have been identified relating to sample representivity, sample processing and interpretation that providing they are overcome promise to add materially to the effectiveness of exploration applied to the search for gold deposits.

Grant 192 GEOCHEMICAL EXPLORATION FOR GOLD

Ian Nichol[1] and Gene S. Shelp[2]

INTRODUCTION

The background to the investigation lies in the fact that gold deposits of the Canadian Shield have a wide variety of characteristics relevant to the search for further deposits. These include occurrence in a range of host rocks, structural settings, varying mineralogy with gold occurring alternatively in pyrite, free gold or as tellurides and wide variations in the grain size of the gold. Superimposed on this diversity of characteristics of the gold deposits and mineralization themselves, exploration is further complicated by wide diversities in the nature of associated glacial overburden. It is to be expected that the geochemical response due to gold mineralization in glacial overburden will vary according to features both of the primary deposits and surface overburden. Effective exploration should as far as possible be capable of detecting as wide a range of deposit types in different environments as possible.

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One of the commonest geochemical exploration procedures adopted in areas of glacial overburden involves the sampling of glacial till although the sampling of specific soil horizons and humus is also employed in certain cases. Depending upon the depth of the glacial overburden till samples may be obtained by surface sampling, trenching or deep overburden sampling employing various drilling techniques. Treatment of the sample may involve the direct analysis of a certain size fraction of the till. Frequently a heavy mineral concentrate is obtained from the sample by tabling and heavy liquid separation. Documented case histories indicate the contribution of these methods in the discovery of several important gold deposits, (Gray, 1983, Averill and Zimmerman, 1984, Sauerbrei et al., 1986 and Thomson et al, 1986) or alternatively their ability to identify known deposits (Closs and Sado, 1979, Bird and Coker, 1986).

As indicated previously the objective of the current investigation was to examine the nature of gold dispersion associated with a variety of gold deposits and thereby assess the effectiveness of commonly adopted methodology. On the basis of the results it was hoped to identify ways by which exploration effectiveness may be increased.

This report presents a review of results obtained, earlier results having been described previously, Nichol and Shelp (1985) Shelp and Nichol (1986).

RESULTS AND CONCLUSIONS

Work undertaken has been based on a relatively small number of samples but the consistency of the results allows some confidence in the conclusions that can be drawn.

1. Till samples collected by reverse circulation drilling are deficient in fine grain sized material relative to the grain size of the material being sampled.

2. Till samples contain from 20% to 50% of silt and clay-sized material.

3. Heavy mineral concentrates are biased towards recovering the minus 500 plus 63 µm fractions and include only an insignificant proportion of silt and clay-sized material.

4. The non-magnetic heavy mineral concentrates show a marked enhancement of gold content relative to the light mineral fraction.

5. The extent to which gold particles are preferentially enriched in the heavy mineral concentrate tends to decrease with decreasing particle size, Wang and Poling (1983).

6. In certain instances significant concentrations of gold remain in the light mineral fractions.

7. The proportion of total gold content concentrated in the heavy mineral fraction varies in the range 4% to 15% and therefore does not give a reliable measure of the total contained gold in the sample.

8. The majority of gold in heavy mineral concentrates occurs in the minus 125 μm fraction where there is a marked reduction in the recovery efficiency of the gravity table with decreasing grain size and variation in shape.

9. Inter-laboratory comparisons display marked variations in the concentration of gold in the heavy mineral concentrates, the weight of the heavy mineral concentrates, and thus the absolute content of gold recovered in the heavy mineral concentrates. Comparisons of the grain size distribution of gold in heavy mineral concentrates indicates in some cases marked variation between laboratories. A heavy mineral concentrating procedure involving a closed system of wet panning and heavy liquid separation indicates that significant proportions of the total gold in a sample occur in the intermediate heavy mineral fraction (S.G. >2.9 <3.3) and a major proportion in the light mineral fraction suggesting varying degrees of liberation of the gold. Whilst recognising the existence of these inter-laboratory variations, their significance in terms of exploration is not known, but nevertheless they indicate the importance of taking into account the sample preparation procedure adopted in interpreting data. In order to try to identify the cause of these variations in gold contents the mineralogical composition

of the concentrates was examined. Binocular microscope examination of individual size fractions revealed the existence of gold spheres and irregularly shaped particles in certain fractions. These were mounted on graphite discs and then examined by scanning electron microscope. Spheres of up to 150 µm diameter (Plate 1) were noted and irregularly fractures gold grains (Plate 2). Semi-quantitative spot analyses of the surface of a number of these gold grains indicated compositions varying from almost 100% Au or 100% Ag to mixed compositions of 50% Au, 27% Ag, 12% Cu and 5% Zn. Considerable interest has risen from the description of gold spherules in till that contain varying amounts of Au, Ag and Cu and are considered to have formed by chemical precipitation (DiLabio et al., 1985). However, the association of gold spherules with fractured grains whose texture suggests deposition from a melt raises doubts as to their origin. Further investigation is necessary to try to identify their origin.

10. Notwithstanding the indicated potential limitations of gold exploration based on heavy mineral concentrate analyses using commonly adopted procedures, heavy mineral concentrates can provide unique information on the type of source mineralization and distance of transport based on a consideration of the mineralogy of the heavy mineral concentrate and shape of the gold grains.

11. Anomalous gold contents occur in the silt and clay-sized fraction of tills associated with both the Owl Creek and Hemlo deposits that indicates these deposits can be identified on the basis of the direct analysis of the fine grain sized fraction of till.

12. The distribution of gold in hydraulically equivalent fractions of the minus 63 µm portion of the sample varies with deposit type indicating variations in the size and/or shape of the gold grains within the silt and clay size fraction.

13. Comparison of gold dispersion in the non-magnetic heavy mineral fraction and the minus 63 µm fraction of tills associated with the Owl Creek Deposit shows very comparable dispersion trains.

14. The analyses of the silt and clay-sized fraction, however, is also suited to the detection of fine-grained gold deposits that are not amenable to detection on the basis of heavy mineral concentrate analyses and thus offers the opportunity for greater effectiveness of gold exploration.

15. Analyses of silt and clay-sized fractions reduce the samp representivity problems associated with analyzing coarser fractions, inherent in basing exploration solely on the analysis of the heavy mineral concentrate.

16. Having regard to variations in the character of sought after gold deposits, particularly the particle size of the gold grains it may be concluded that exploration reliability can be increased by analyzing both the silt and clay-sized fraction and the heavy mineral concentrate.

17. In recognising indications of potential weaknesses of current adopted procedures, it is fully recognized that conventional procedures have played a key role in the discovery of a number of important deposits. However, it is considered that by the adoption of various modifications in exploration methodology the overall effectiveness of exploration directed to the search for gold deposits may be improved.

FUTURE WORK

As described above work to date has identified some areas in which the reliability of exploration methodology may be improved and continuing work under the terms of a broader based investigation is being directed towards this end. Aspects being considered include:

1. Substantiating the validity of the results by analyzing more samples from more deposit types and with varying spatial relationship to mineralization but despite the small number of samples analysed the consistency of the results bears testimony to their reliability.

2. Investigating the mineralogical mode of occurrence of gold in silt-sized fractions, i.e. whether it is of mechanical or hydromorphic origin.

3. Examining the representivity of samples collected by a variety of drilling systems and ways of improving the representivity of samples collected from different systems. This involves the examination of the use of a floculating agent to recover fine grained suspended matter normally last from the collection bucket used in reverse circulation drilling.

4. Examining ways of improving the reliability that can be attached to gold analyses of heavy mineral concentrates, with respect to relation to mineralizaion.

5. Identifying an exploration methodology that will improve the overall effectiveness of geochemical exploration applied to gold exploration.

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The major component of the work described constituted the M.Sc. research topic of G.S.S. under the terms of O.G.R.F. grant 192 awarded to I.N. In addition to the Ontario Geoscience Research Fund, assistance for this investigation was provided by C.F. Minerals Ltd., Cominco Ltd., Esso Minerals Canada, Inco Ltd., Kidd Creek Mines Ltd., Noranda Explorations Ltd., Nuclear Activation Services Ltd., Overburden Drilling Management Ltd., Placer Development Ltd., Teck Explorations Ltd., and X-Ray Assay Laboratories Ltd. Without this generous cooperation and assistance the investigation would not have been possible.

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APPENDIX 1

THE DISTRIBUTION AND DISPERSION OF GOLD IN GLACIAL TILL ASSOCIATED WITH GOLD MINERALIZATION IN THE CANADIAN SHIELD

by

GENE SIDNEY SHELP

A thesis submitted to the Department
of Geological Sciences in conformity
with the requirements for the degree
Master of Science

Queen's University
Kingston, Ontario, Canada
December, 1985

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Abstract

The results described relate to an investigation aimed at establishing the distribution of gold in glacial till, with a view to improving search techniques used in exploration for gold deposits.

The diversity of gold deposits in the Canadian Shield, as exemplified by host rock lithologies, mineralogy and grain size of the gold would be expected to give differences in the secondary response in the associated overburden. Common exploration procedures use the analysis of either the heavy mineral fraction or a particular size fraction of the tills. However, in light of the problems posed a more comprehensive exploration procedure may have to be adopted in order to locate all types of gold mineralization.

Bulk till samples were collected from various sites associated with the Owl Creek, Hemlo and McBean Mine deposits and the Green Lake occurrence. Grain size analyses were carried out on the original till samples and on the derived heavy mineral concentrates. The concentration of the gold in the sample fractions was determined by Instrumental Neutron Activation Analysis.

The results allow a number of conclusions to be drawn.

1) Grain size analysis of the minus 2 mm fraction of tills indicates that the silt and clay fraction constitutes 20-50 % of this fraction, whereas, the equivalent heavy mineral concentrates are dominantly composed of coarser minus 500 plus 63 µm material.

2) The amount of gold present in the heavy mineral concentrates of tills generally represents less than 15 % of the total gold in the original samples. In addition, the proportion of the total gold recovered in the heavy mineral concentrate varies from 4 to 15 %. These findings point out the potential unreliability of evaluating heavy mineral gold data.

3) The size distribution of gold within the heavy mineral concentrate indicates that the majority of the gold is contained in the minus 125 µm fraction.

4) The concentration factor (the original sample weight divided by the heavy mineral concentrate weight) varies between samples. Hence, in samples which initially contain the same amount of gold, the gold concentration of the heavy mineral concentrate will vary in accordance with the quantity of heavy minerals. A true interpretation with respect to gold can only be achieved by re-expressing the gold contents of heavy mineral concentrates in terms of the absolute amount of gold in heavy mineral concentrates.

5) A comparison of the heavy mineral concentrates obtained on a specific sample by different laboratories shows marked differences in the weight of the heavy mineral concentrate obtained, the gold content of the heavy mineral concentrate and, despite correction for the concentration factor, the weight of gold in the heavy mineral concentrate.

6) Analyses of the silt and clay size fraction (minus 63 µm) of

samples associated with gold deposits show anomalous gold contents. An anomaly at the Hemlo deposit extends at least 500 meters down-ice from mineralization.

7) The analysis of the silt and clay fraction reduces the sample representativeness problem associated with analysing coarser fractions.

8) A comparison of the gold distribution in heavy mineral concentrates and the minus 63 µm fraction of till down-ice from the Owl Creek deposit indicate broadly similar dispersion patterns.

In conclusion, although the results are based on eight till samples, their consistency permits some general conclusions to be drawn. The silt and clay and the heavy mineral concentrate analyses provide different information and in view of the diversity of exploration targets and surface environments exploration reliability can be increased by analysing both a representative silt and clay fraction (minus 63 µm) and a representative heavy mineral concentrate.

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Chapter 1

Introduction and Review of Previous Work

1.1 - Objectives

The objectives of this programme were: 1) to study the nature of the geochemical dispersion of gold in glacial sediments associated with gold deposits, 2) to evaluate the adequacy of the current geochemical exploration techniques, and 3) to improve where possible the reliability of the geochemical techniques used in gold exploration.

1.2 - Background

The geological diversity of gold deposits, in terms of the host rock lithology, the mineralogy of the deposit and especially the mineralogical mode of occurrence of the gold and the size of gold grains, coupled with diversity of secondary environments in which these gold deposits occur require an exploration approach that is capable of detecting all possible types of gold deposits.

1.2.1 - History of Gold Exploration

During the period 1934-1968, the fixed price of gold resulted, with a few notable exceptions, in very little interest in gold exploration and any research and development associated with developing methods for gold exploration. The increased price of gold

and the relatively poor market for other metals has led to a renewed interest in gold exploration.

Historically, elements associated with gold mineralization such as arsenic, antimony and mercury have been used as pathfinders in geochemical exploration to aid in identifying gold deposits because of the lack of any adequately sensitive method for routine gold analysis. The disadvantages of this method were that not all gold deposits have associated pathfinder elements and, conversely, not all anomalous concentrations of pathfinder elements were associated with gold deposits. In the interim, the development of more sensitive analytical techniques, such as atomic absorption and neutron activation analysis, have permitted the direct analysis of geochemical samples with low concentrations of gold. This approach is currently used in geochemical exploration for gold deposits.

1.2.2 - Sample Type, Collection, Preparation and Size

In areas of glacial overburden the most commonly used sample medium in geochemical exploration is glacial till, although, the sampling of specific soil horizons and humus is also employed. Some of the earliest work in the Canadian Shield employing till geochemistry was carried out in the early 1960's by Dreimanis (1960) in the Noranda area, by H.A. Lee (1963) in the Kirkland Lake area and by Fortescue and Hughes (1965) in the vicinity of the Kidd Creek orebody at Timmins. The premise on which glacial till became an acceptable sample medium in geochemical exploration is defined by Averill (1978) who stated that, " till exploration employs the principle that the tops of ore deposits that sub-crop beneath glacial

overburden were exposed to the base of continental ice sheets, eroded and dispersed in till to form exploration targets that are much larger than the actual orebodies".

The lodgement facies of glacial till has proven to be the most useful sediment for exploration because 1) lodgement till is derived from processes occurring at the base of the glacier, 2) lodgement till usually contains locally derived material as its main component, and 3) lodgement till tends to be deposited locally, up to 1.5 to 2 miles from its source (Nichol and Bjorklund, 1973; Averill, 1978).

The Canadian Shield is a prime example of an area where multiple glaciations and thick overburden have seriously complicated the interpretation of geochemical data. Glacial statigraphy models for the Canadian Shield have been proposed by Averill (1978) and Fortescue (1983). Averill identified three general models (Figure 1.1a-c). In the first model (Figure 1.1a), a single till sheet overlies the mineralization. Glacial erosion of the exposed zone resulted in a simple dispersion train. In this situation, surface sampling may prove to be quite successful in detecting the underlying deposit. A more complicated situation is shown in the second model (Figure 1.1b). Multiple till sheets overlain by a thick sequence of glaciolacustrine sediments has resulted in the absence of a signature at the surface. In this situation, overburden drilling would be the most logical approach with reasonably good chances for success. The final and most complicated model, is the situation where the deposit has outcropped in a bedrock low (Figure 1.1c). The first glacial advance buried the deposit and protected it from further glacial erosion. In this case, neither surface or deep overburden sampling may be very successful.

Figure 1.a Simple mechanical dispersion train.

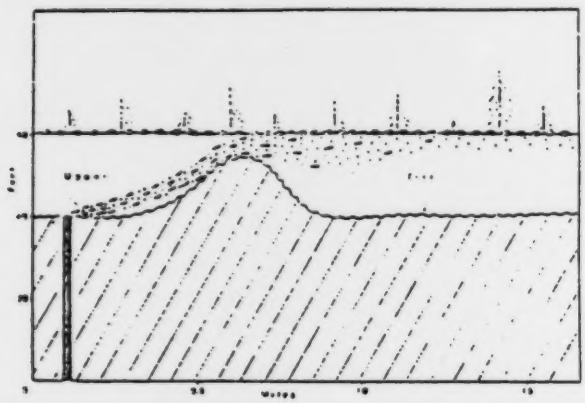


Figure 1.b Mechanical dispersion train: two tills, source on bedrock high.

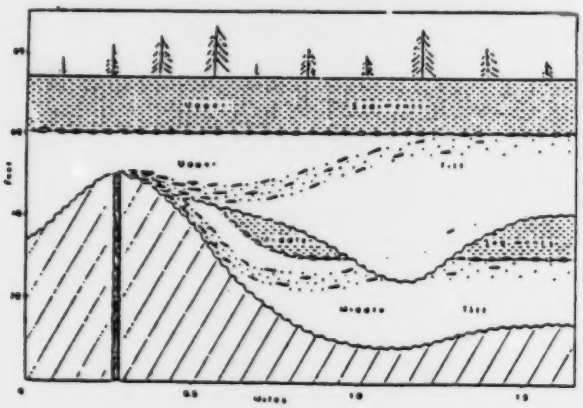


Figure 1.c Mechanical dispersion train: two tills, source on bedrock depression.

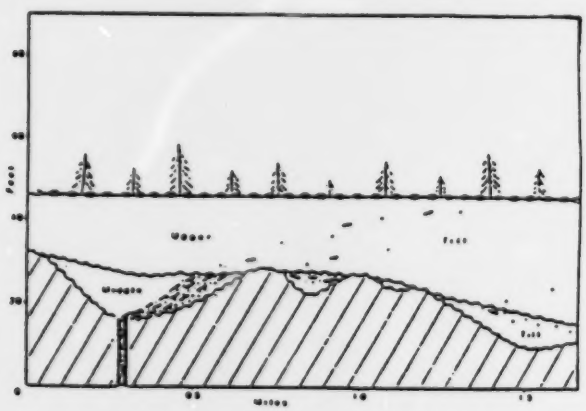


Figure 1.1 Glacial stratigraphy models for the Canadian Shield (after Averill, 1978).

Even though the older till may be sampled, further complications arise in following the dispersion train, due to the fact that this older till is only preserved in the bedrock lows.

Depending upon the depth of the overburden, till samples may be obtained by surface sampling, trenching or deep overburden drilling techniques. Deep overburden drills range in size from portable gas powered drills (ie. Pionjar, Cobra) to large hydraulic drills mounted on tracked vehicles (ie. Acker P38, Longyear). The use of portable drills is restricted by the fact that they cannot penetrate bouldery tills or even hard compact lodgement tills. The most common overburden drill in use today is the reverse circulation or dual-tube drill. Water and air passes between the outer wall of the inner tube and the inner wall of the outer tube (Figure 1.2) The cuttings released by the tri-cone bit are retrieved up the center of the inner tube , through a cyclone separator and finally are collected in a sample bucket. The problems that arise with this method are two-fold, a representative sample is not collected and thin sheets of lodgement till common in the Canadian Shield are difficult if not impossible to identify. As an illustration of the former problem, work done by Averill and Thomson (1981) shows that the minus 63 µm fraction constitutes less than 5 % of the material collected in the sample bucket (Figure 1.3). The original sample consisted of greater than 50 % minus 63 µm material indicating a significant loss of this fraction during the collection of the sample. Examination of the material in the recirculation tank revealed a predominance of the minus 63 um fraction.

An alternative to the reverse-circulation drill is the

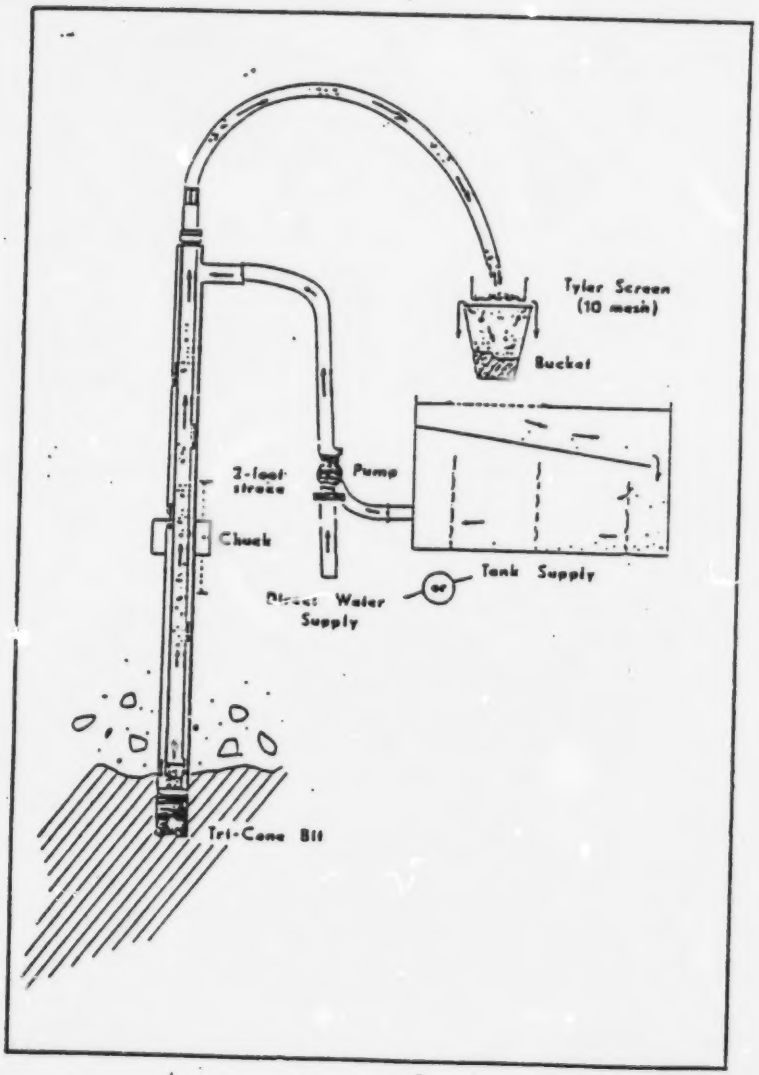


Figure 1.2 Illustration of the reverse circulation drill (from Skinner, 1972).

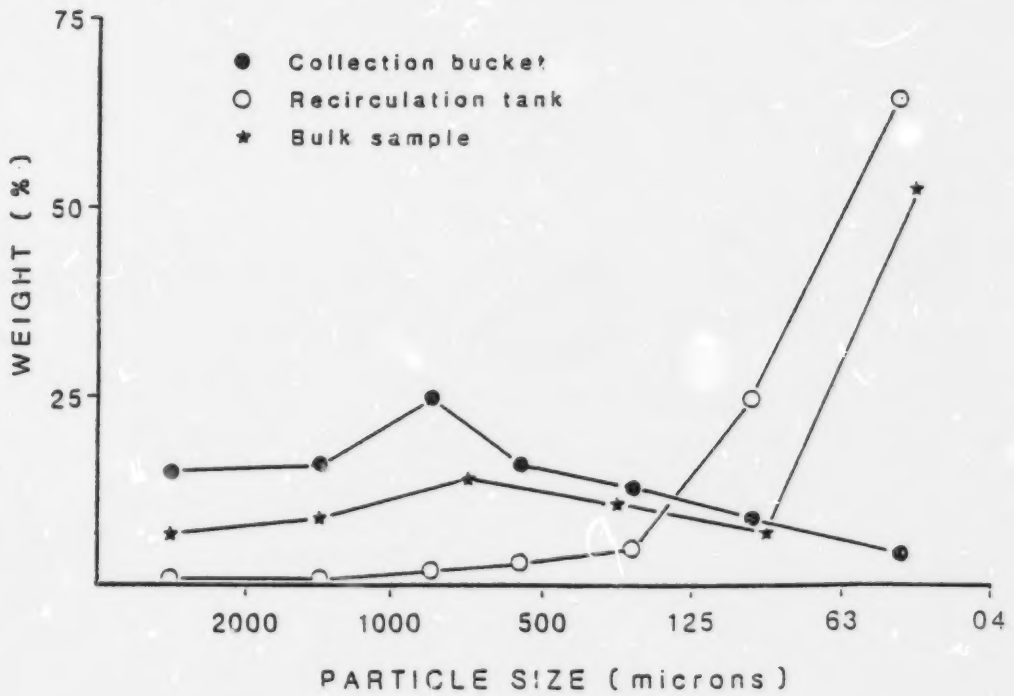


Figure 1.3 A comparison of the particle size distribution of bulk sample to those of the collection bucket and recirculation tank (from Averill and Thomson, 1981)

rota-sonic drill. The advantage of the sonic drill is that an undisturbed sample is retrieved and this allows the collection of a representative sample and permits detailed and reliable logging of the glacial stratigraphy. The drawbacks to the sonic drill are that the price per meter drilled is more than double that by reverse-circulation and that the excessive weight of the drilling rig restricts the use of the drill to relatively solid ground.

Treatment of the field sample may involve the direct analysis of a certain fraction of the till or, more frequently, the preparation of a heavy mineral concentrate which is obtained either by tabling or a comparable technique followed by heavy liquid separation. It has also been noted that fine grained material is lost from the table in the effluent and this suggests that fine grained gold is not being recovered by the heavy mineral procedure (Averill and Thomson, 1981).

In a number of instances geochemical techniques used in gold exploration have been those techniques that were developed for base metal exploration which involve the collection of a 200 to 500 g sample and the direct analysis of a sub-sample. This is considered adequate for base metal exploration since concentrations of interest are in the tens of ppm and the elements of interest occur as minor components of major constituents of the sample. In the case of gold, concentrations in the tens of ppb are of significance and this coupled with the frequent occurrence of gold in the particulate form as free gold constitutes a serious problem of sample representativeness. Clifton et al.,(1969), indicate that a sample size containing twenty particles of gold is required to give a precision of $\pm$ 50 % at the 95 % confidence level. For example, an analytical sample weight of 15 g

is required for a gold concentration of 64 ppb, and a gold particle flake diameter of 31 µm (diameter = 10 times thickness). In comparison a 6.5 kg sample size is required for the same concentration involving a gold flake particle diameter of 250 µm. Further, if a precision of better than ± 50% at the 95 % confidence level is required then commensurately larger sample weights will be needed. These features are based on the following assumptions: 1) the gold particles are distributed randomly, 2) the gold particle mass is uniform, 3) the gold particles make up less than 0.1 % of all particles, 4) the samples contain at least a 1000 particles of all kinds and 5) analytical errors are absent.

The size of the sample required for an acceptable precision and confidence levels refers to the analytical sample size and the minimum size of field sample (Clifton et al., 1969; Harris, 1982). As stated previously, a heavy mineral concentrating procedure is used to reduce the representative field sample to a representative analytical sample. Tourtelot (1968) states that the heavy mineral concentrating techniques are most effective when the sample has a narrow, particle size range. Wang and Poling (1983), in reporting the efficiency of heavy mineral concentrating techniques in recovering placer gold noted that recovery efficiency declined with decreasing gold particle size. The recovery also varied with the particle size of the bulk sample feed. For example, the recovery of gold flakes of 200 µm in diameter from the sluice improved by greater than 20 %, from an initial 64 % to 85 % , when the particle size of the feed was reduced to the minus 4 mm from the minus 16 mm size material (Poling, pers. comm., 1985). Furthermore, the results seem to indicate that the recovery of gold

finer than 2 mm shows an even greater improvement. The accepted practice in exploration today in the preparation of heavy mineral concentrates is to pass the minus 2 mm fraction of the till over the separatory table.

1:2:3 - Special Aspects of Heavy Mineral Concentrates

Documented case histories indicate either the contribution of this method in the discovery of several important gold deposits (Grey, 1983, Averill and Zimmerman, 1984, Sauerbrei et al., 1985 and Thomson et al., 1985) or alternatively, their ability to identify known deposits (Closs and Sado, 1979; Stewart, 1981; DiLabio, 1982; MacEachern, 1983; Gleeson et al., 1984 and Bird and Coker, 1985).

In some cases, analysis of the heavy mineral concentrate is preceeded by a visual examination of the material to determine the number and morphology of the gold grains. For example, the morpholgy and number of the gold grains in heavy mineral concentrates from till samples collected in the Waddy Lake area in Saskatchewan were examined to determine, 1) the particle size population, (as a common size indicates a common source), and 2) the contribution that each gold particle will make to the eventual assay of the concentrate (Averill, 1984).

Gold present in glacial sediments may be syngenetic and/or epigenetic in origin. Therefore, the source of the gold and the distance from the source is a major concern. It is considered that the number and the morphology of the gold grains in the sediments gives a good indication as to the distance the gold has travelled. A classification of the morphology of gold grain and the distance from

its source has been described by Averill and Zimmerman (1984) (Figure 1.4). A brief outline is as follows:

a) delicate - indicating a transport of 100 metres or less,

b) irregular - indicating a transport of 100 to 1000 metres,

c) abraded - indicating a transport of > 1 km,

d) rounded - indicating fluvial rather than ice transport.

The origin of speroidal gold grains present in till has been examined by Newsome and McIvor (1984). These authors examined spheroidal gold grains using an electron microprobe. Based on the shape, texture and composition of the spheroidal gold grains, they suggested an in-situ origin.

The number and size of the visible gold grains in the heavy mineral concentrate is determine together with the gold content attributable to them, in order to determine if one gold grain could account for the majority of the contained gold. For example, a gold particle 125 µm in diameter and with a thickness equalling one fifth of this diameter will result in a concentration of 1200 ppb if the weight of the concentrate is 5 grams (Figure 1.5). If the total gold content of the heavy mineral concentrate was contained in a single gold particle, the sample would not be considered significant.

1:3 - Geochemistry of Gold

Gold, the noblest metal, is a member of Group 1B of the periodic table. The only naturally occurring gold isotope has a atomic number of 79 and atomic weight of 197. Gold occurs principally in three oxidation states: Au (0), native gold; Au (I), aurous and Au (III), auric (Boyle, 1979).

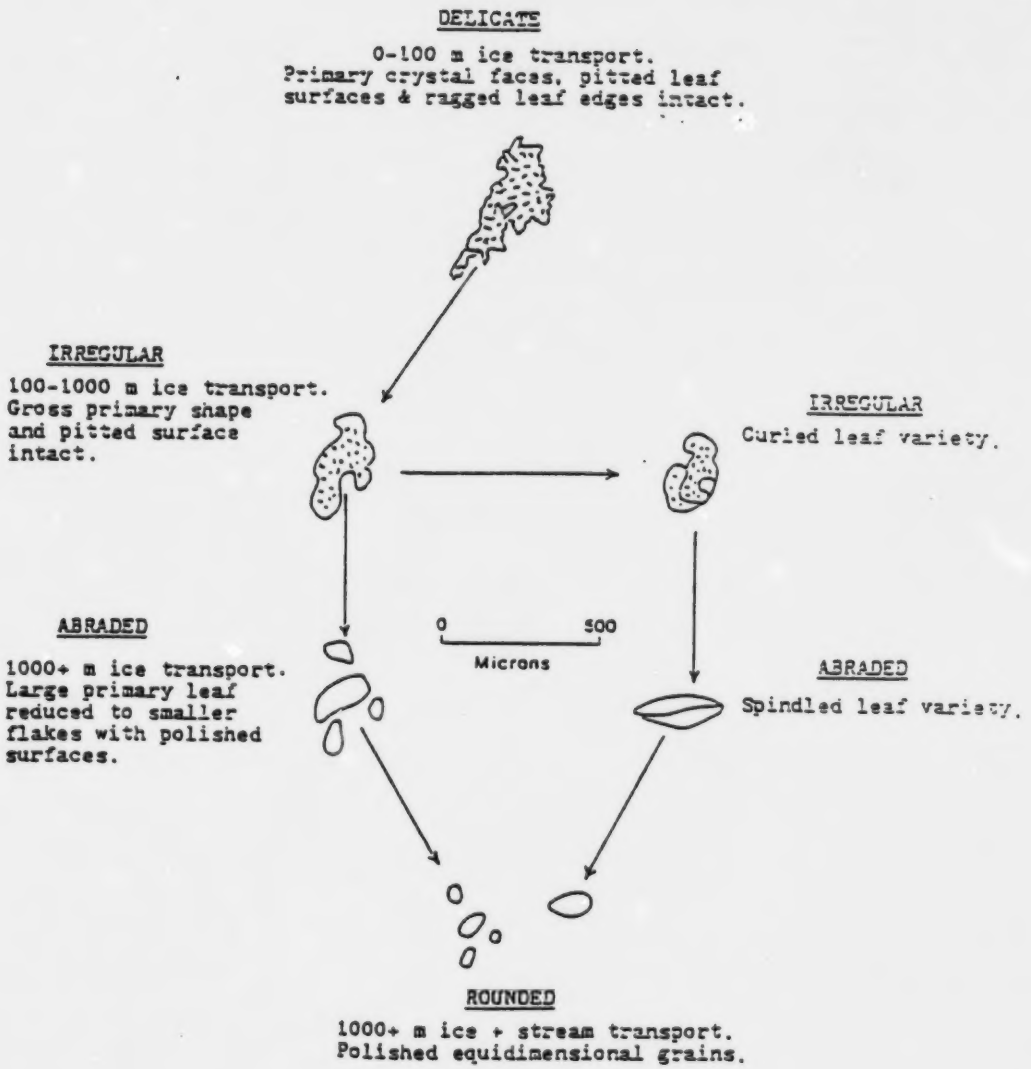


Figure 1.4 Effects of glacial transport of gold particle size and shape (after Averill and Zimmerman, 1984).

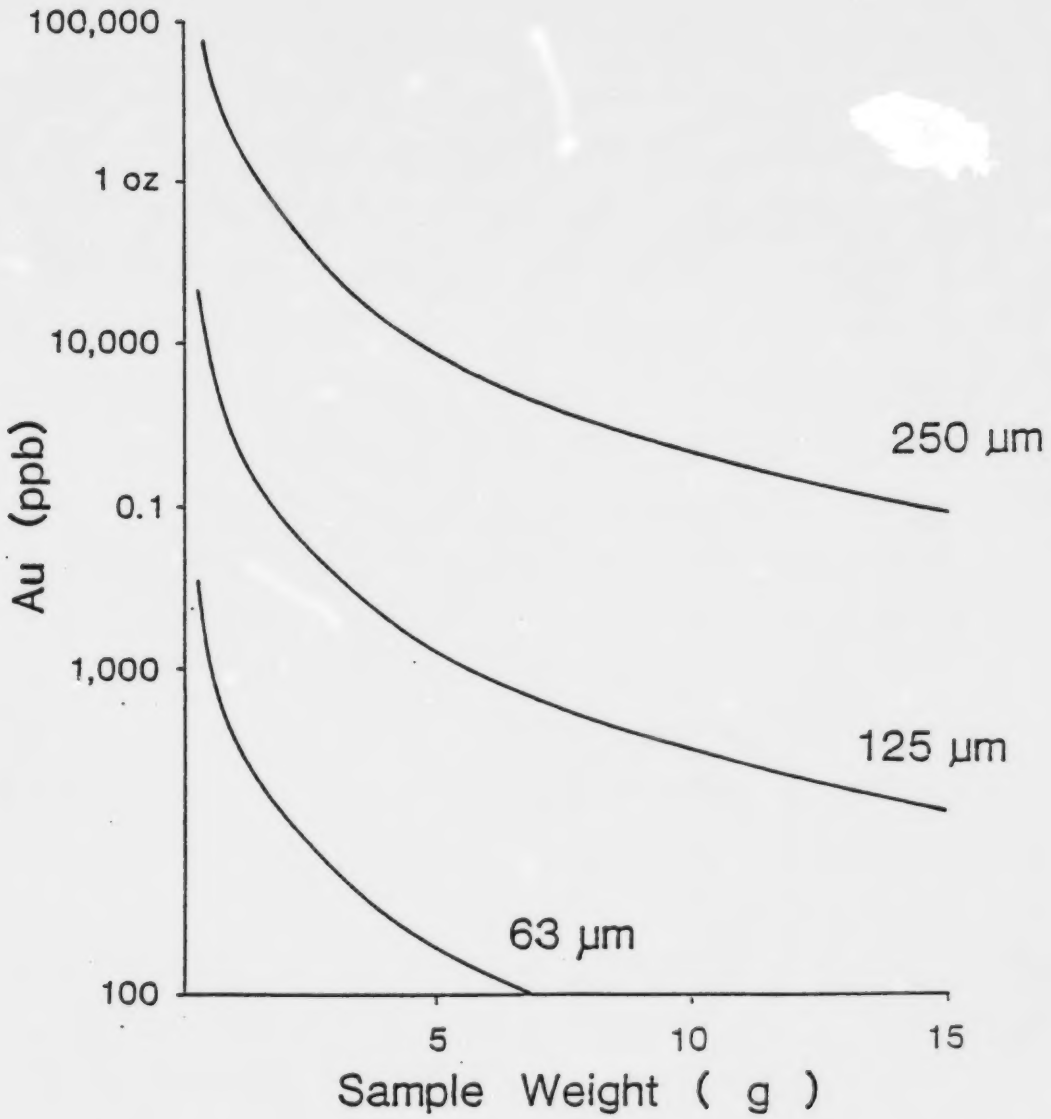


Figure 1.5 The concentration that a gold particle of a specific size will contribute to a certain weight of heavy minerals (modified from Averill and Zimmerman, 1984).

The common gold minerals are native gold and gold tellurides i.e., calaverite, krennerite, sylvanite, nagyagite, muthmannite and petzite. Gold also occurs in association with a variety of other minerals but of major importance is the occurrence of native gold as inclusions or as a lattice constituent (Boyle, 1979). As a lattice constituent it substitutes in Cu and Ag sites of sulphide minerals.

Sulphide gold termed "invisible gold" is most commonly associated with pyrite and arsenopyrite and may assay more than 30 ounces/ton (Springer, 1982). At the Carlin and Cortez Mines, Nevada gold occurs as submicroscopic (<0.5 μm) inclusions in pyrite and arsenopyrite and as free gold 10-20 μm in diameter (Wells and Mullens, 1973). In a review of placer gold deposits in China, the clay fraction has been found to contain 5 to 10 times the head assay of the deposit (Wang and Poling, 1983). Within the Canadian Shield, for example, the Agnico-Eagle Mine (Barnett et al., 1983) and Bousquet deposits (Valliant and Hutchinson, 1982), gold is also present as inclusions within pyrite grains. The Cinola deposit in the Queen Charlotte Islands, British Columbia is classified as a Carlin-type gold deposit, (Champigny and Sinclair, 1982). The gold is present as inclusions in chalcopyrite (approximately 10 μm in size) and as micron sized gold associated with silicified veins. It is evident that gold, of a particle size less than 20 μm, is present in significant amounts in various gold deposits types. This suggests that fine gold may also be present in glacial sediments found at similar deposits. Therefore, it is important to collect a representative sample of glacial sediment during geochemical exploration programmes in order to improve the chances of detecting these deposits types.

Boyle (1979) demonstrates the diversity of gold deposits by classifying them into eight types based upon the host rock lithologies, the structure and mineralogy of the deposit. They are as Boyle says:

" 1) Auriferous porphyry dykes, sills and stocks; auriferous coarse-grained granitic bodies, aplites and pegmatites.

2) Auriferous skarn type deposits.

3) Gold-silver and silver-gold veins, stockworks, lodes, mineralized pipes, and irregular silicified bodies in fractures, faults, shear zones, sheeted zones and breccia zones essentially in volcanic terranes.

4) Auriferous veins, lodes, sheeted zones and saddle reefs in faults, fractures, bedding-plane discontinuities and shears, drag folds, crushed zones and openings on anticlines essentially in sedimentary terranes; also replacement tabular and irregular bodies developed near faults and fractures in chemically favourable beds.

5) Gold-silver and silver-gold veins, lodes, stockwork and silicified zones, etc. in a complex geological environments, comprising sediments, volcanics and various igneous intrusives and granitized rocks.

6) Disseminated and stockwork gold-silver deposits in igneous, intrusive, volcanic and sedimentary rocks.

a) Disseminated and stockwork gold-silver deposits in various igneous intrusive bodies,

b) Disseminated gold-silver occurrences in volcanic flows and associated volcaniclastic rocks,

c) Disseminated gold-silver deposits in volcaniclastic and sedimentary beds: Deposits in tuffaceous rocks and iron formations and deposits in chemically favourable sedimentary beds.

7) Gold deposits if quartz-pebble conglomerates and quartzites.

8) Placers: eluvial and alluvial.

a) Eluvial, including those developed in karst environments.

b) Alluvial.

c) Fossil eluvial and alluvial."

The mobility, migration, concentration or dispersion of gold during the oxidation of gold deposits is strongly influenced by the type of gold deposit, degree of fracturing, climatic factors, water table and organic agents (Boyle, 1979).

The mineralogy of the gold in the primary deposit plays an important role in determining the extent of the dispersion of gold in the secondary environment. The solubility of gold is increased when released in ionic form from sulphide lattices or as colloids where gold subsequently migrates in solution or suspension (Boyle, 1979).

The chemical migration of gold in oxidizing waters during the oxidation of gold mineralization occurs as:

a) native metal as colloids,

b) hydroxyl complexes, for example, $Au(OH)$, $[Au(OH)_4]^-$,

c) dissolved thio complexes, for example, AuS^-, $[Au(SO_3)_2]^{3-}$,

d) dissolved halide species which are mainly chloride complexes, for example, $(AuCl_2)^-$, $(AuCl_4)^-$,

e) organic complexes or complexes derived from organic matter for example, cyanide ,$[Au(CN)_2]^-$, and thiocyanate complexes , $[Au(CNS)_4]^-$,

f) adsorbed to various organic materials, for example, humic acid,

g) absorbed to inorganic colloids, for example, hydrous iron and manganese oxides (Lakin, 1974; Boyle, 1979).

The mobility and precipitation of gold is largely controlled by the pH and Eh of the oxidizing solutions and environment. Thio and cyanide complexes are only stable under alkaline conditions while chloride complexes are stable in acid or near neutral pH conditions. The pH is controlled by the various acids, especially sulphuric acid, which is derived by the oxidation of sulphides and hydrolysis of sulphates and by the neutralizing effects of carbonate or gangue material. In summary, gold is relatively mobile in acid or strongly alkaline environments and therefore the areas of enrichment are those of weakly acid, neutral or weakly alkaline conditions (Boyle, 1979).

The most important mechanism for precipitating gold in sulphide deposits is the interaction of ferrous iron with an auriferous solution in zones of low oxidation. Other mechanisms for precipitating gold are by:

a) changes in pH, as the pH increases the chloro-complexes will break down whereas if the pH is decreased the the alkaline complexes will be destroyed, resulting in the precipitation of gold,

b) manganous ions (Mn^{2+}) in weakly acid, neutral and weakly alkaline solutions,

c) the adsorption or co-precipitation of negatively charged gold complexes and colloids by positively charged substances [hydrous ferric oxide (limonite), clay minerals, humic and silicate gels],

d) various natural reductants (sulphides, carbonates, carbonaceous substances, native minerals),

e) the co-precipitation or adsorption by numerous supergene minerals (bismuthinite, jarosite, malachite, azurite, sulphur, phosphates, etc.),

and f) the precipitation by hydrogen sulphide formed during the oxidation of sulphides or by the bacterial reduction of sulphate (Boyle, 1979).

The average gold content of soils and glacial sediments within the Canadian Shield is approximately 5 ppb; slightly higher contents are found in the humus layer relative to the underlying soil horizons. The silt and clay fraction of the soils generally has a higher gold content than the coarser sand fraction (Boyle, 1979).

In the absence of oxidants and complexing agents, the gold if released from its host remains in situ and grows by the accretion of soluble gold. This may account for the presence of coarse grained gold particles in sediments overlying mineralization which are basically devoid of coarse grained gold.

1:4 - Scope of the Investigation

This programme summarizes the results of an investigation into the nature of gold in glacial till from areas associated with gold deposits within the Canadian Shield. The depth and complexity of the

glacial stratigraphy coupled with the facts that gold is present in low concentrations and that gold frequently occurs as free gold particles limits the effectiveness of conventional geochemical techniques.

The diversity of gold deposits in terms of the host rock lithologies, mineralogy, nature of the gold and the grain size of native gold coupled with the complex glacial processes that deposited the overlying sediment would be expected to give rise to differences in the secondary response in the associated overburden. These features demand that the method of geochemical exploration employed is capable of detecting the primary gold mineralization and the secondary dispersion targets.

The shortcomings of the currently used geochemical exploration techniques and the ways of improving the reliability of geochemical exploration are the subjects of interest addressed in the thesis.

1:5 - Approach to the Problem

Initial work involved a literature search to assess the extent of past and current research concerned with the subject.

Areas in the Canadian Shield were identified which would offer different situations in terms of the type of mineralization, the mineralogy of the gold and the depth and type of overburden associated with the deposit. Of primary concern was the accessibility to glacial tills which contain dispersed material from the deposit of interest.

Based on the predetermined gold content of the various tills associated with gold deposits, large bulk samples of the tills were collected for detailed examination. Aspects examined included the

mineralogy, the distribution of the gold within the glacial sediment and the gold content. Analysis was carried out by instrumental neutron activation analysis (INAA). Since INAA is non-destructive, any samples containin highly anomalous contents of gold can be investigated mineralogically using a binocular microscope. Subsequently, the currently used sample collection and processing techniques were evaluated with the objective of improving the reliability of the techniques.

Finally, questionable results obtained from different processing laboratories lead to an in-depth study into the comparability of data received from laboratories employing similar techniques and from laboratories employing a somewhat different process.

1:6 - Organization

The thesis is organized in the following manner:

Chapter 1 introduces the objectives, background to the investigation , the scope of the study and the approach used to identify methods of improving the reliability of geochemical exploration.

A brief description of the regional geology, deposit geology and mineralogy and the glacial geology of the Hemlo, McBean Mine and Owl Creek deposits and Green Lake showing is presented in Chapter 2.

A summary of the sampling, processing and analytical methods are described in Chapter 3.

In Chapter 4, the results obtained during the investigation along with an interpretation and possible explanations are presented.

The summary, conclusions and a brief discussion concerning the

applicability of the results to gold exploration are presented in Chapter 5.

Chapter 2

Description of Study Areas

The areas of the Canadian Shield in which the study was conducted are: the Owl Creek deposit, the Hemlo gold camp, the Green Lake occurrence and the McBean Mine deposit.

As indicated previously, gold deposits occur in a variety of host rocks and structural environments. The recognition of this feature is of prime importance in selecting areas for exploration and has no particular bearing on the present study. In the light of this, only a brief description of the deposits from which material was collected is given.

Of particular importance, however, in the present study is the varied mineralogical mode of occurrence of the gold amongst deposits studied and the varying grain size distribution of gold as these features are preceived as being major controlling factors on the appropriate exploration methodology for searching for comparable deposits.

The areas for study were selected on the basis of the character of mineralization and the nature of the overburden.

2:1 - Owl Creek

2:1:1 - Location

The Owl Creek gold deposit is located in Hoyle Township, 20 km

northeast of Timmins, Ontario (Figure 2.1). The mine, owned and operated by Kidd Creek Mines Ltd., is situated just north of the Kidd Creek metallurgical site which is located off Hwy 101.

2:1:2 - Regional Geology

The deposit is situated in the Abitibi greenstone belt of the Superior Province. The belt is comprised of metasedimentary and felsic to mafic metavolcanic rocks (Figure 2.2).

The volcanic rocks are divided into two groups; the older Deloro Group and the overlying Tisdale Group (Pyke, 1980). The Deloro Group consists of lower andesite and basalt flows overlain by dacites and rhyolites. A lower komatiitic sequence overlain by a thick sequence of tholeittic basalts topped with volcanoclastics make up the younger Tisdale Group.

The Porcupine-Destor fault is the main structural break in the area, extending possibly to the Kapuskasing structure in the west and to the Noranda area in the east (Pyke, 1980).

2:1:3 - Deposit Geology

The footwall rocks to the south consists of a thick sequence of bedded greywacke and argillite overlain by sheared graphitic argillite which host minor gold bearing quartz veins. The main ore zone is hosted by mafic volcanics. At the southern contact of the mafic volcanics with the footwall sediments a zone of auriferous quartz veins is present. The mafic volcanics are capped by graphitic layer which host auiferous quartz veins similar to that found in the

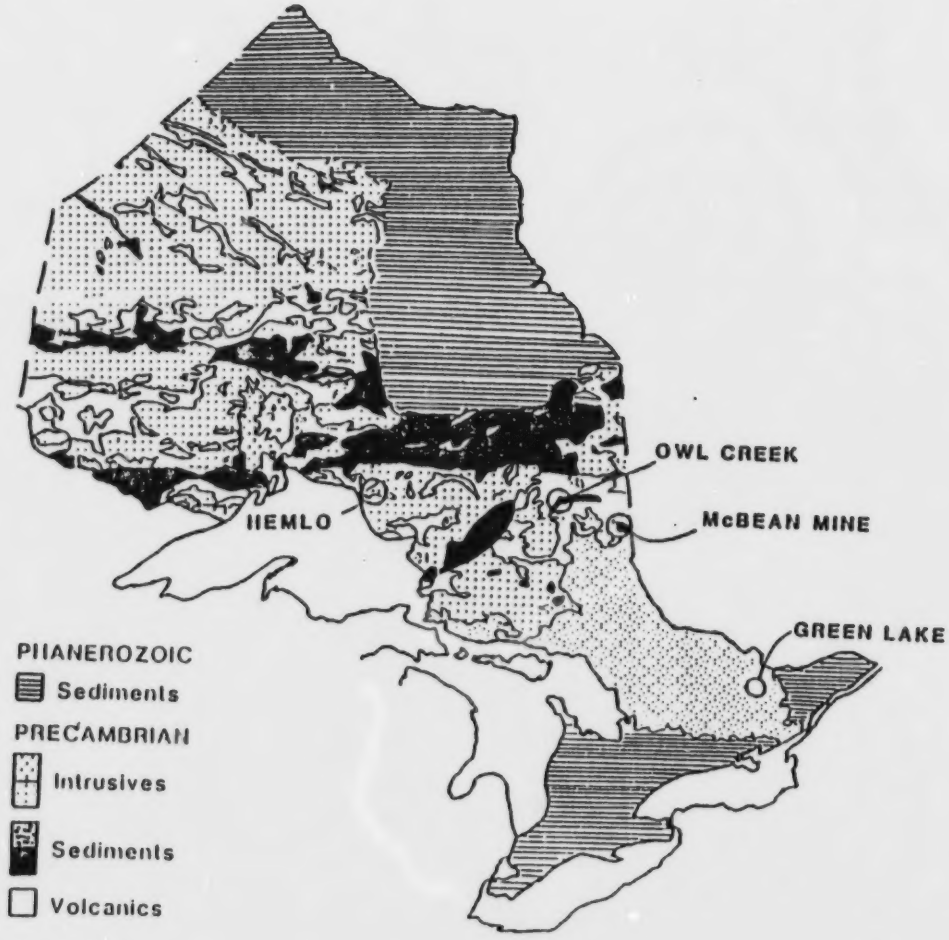


Figure 2.1 Location of study areas.

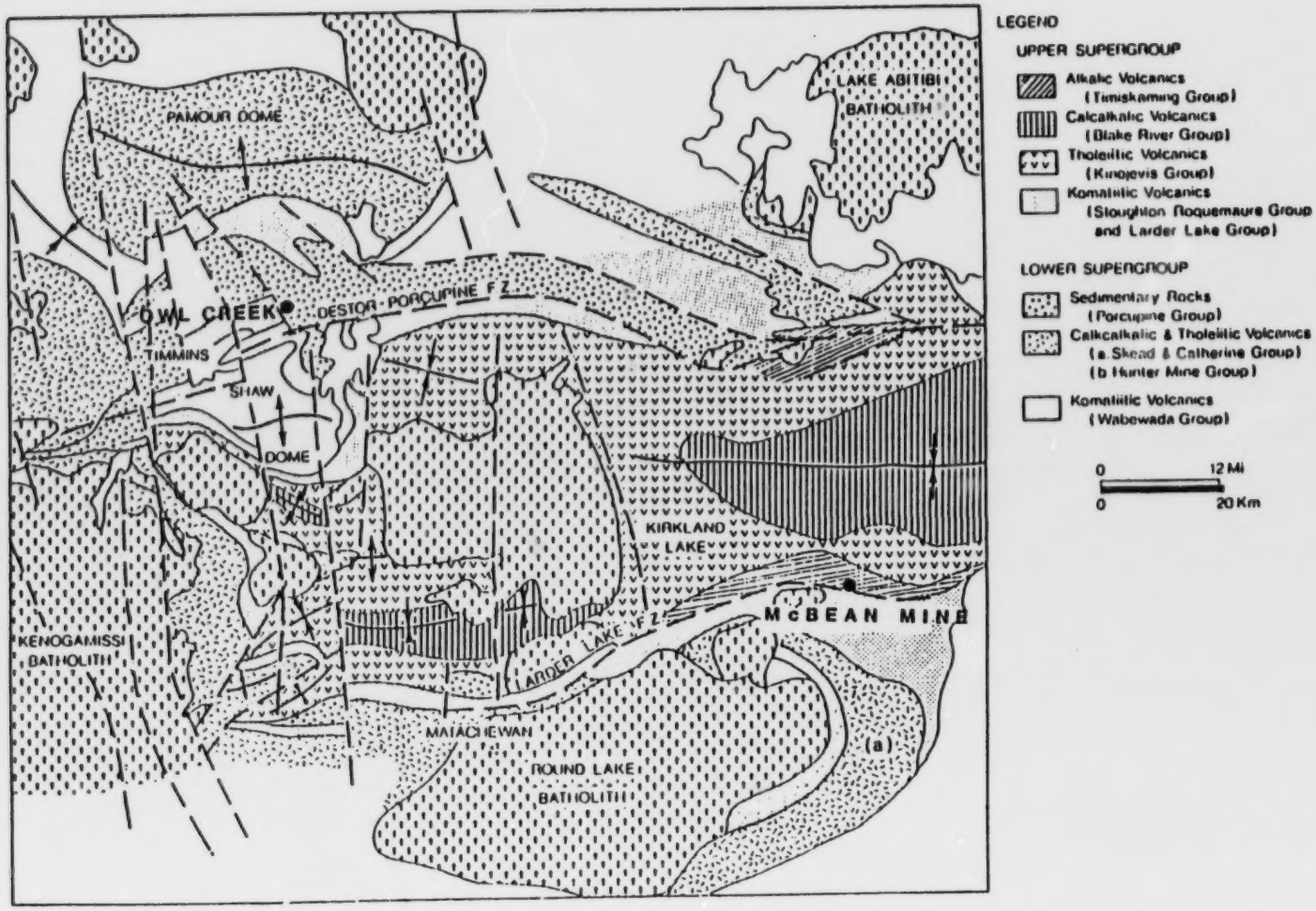


Figure 2.2 General stratigraphy and structure of the Timmins-Kirkland Lake area (Pyke, 1973).

footwall. The hanging wall is a thick unit of bedded greywacke and argillite (Brisbin,1984, Coker, 1984).

The gold mineralization consists of discrete gold grains which occur as inclusions in, or held on the surfaces of fine grained pyrite. The gold also occurs as discrete grains included in quartz veins which are frequently associated with graphite (Bird and Coker, 1985).

2:1:4 - Quaternary Geology

Regionally, a thick sequence of glaciolacustrine sediments is widespread throughout the area. These sediments were laid down during the evolution of glacial lakes Barlow-Ojibway.

Within the open pit four till sequences have been identified by Kidd Creek Mines' Quaternary geologists. Glacial striae indicate an ice direction of 170 degrees for the latest major Wisconsinan or Matheson package and 130 degrees for the late Cochrane re-advance (Bird and Coker 1985).

The sediments that were sampled in the open pit most probably belong to the Matheson sequence. A dark green, unoxidized, highly compacted, silty till contains a high percentage of volcanic and sedimentary clast of local derivation. A buff coloured, silty till stratigraphically overlies the green till. It is loosely compacted and oxidized, and contains a high percentage of quartz clast.

2:2 - Hemlo Area

2:2:1 - Location

The Hemlo gold camp is located 350 km east of Thunder Bay,

Ontario, along Highway 17 (Figure 2.1). The camp consists of three deposits: the Teck-Corona, the Lac Minerals and the Noranda-Goliath deposits. The Trans-Canada Highway passes through the camp, right over the deposit and was probably a significant factor leading to the discovery.

2:2:2 - Regional Geology

Hemlo is situated in a east-west trending greenstone belt in the Wawa Subprovince of the Superior Province. The belt consists of metasedimentary and felsic to mafic metavolcanics which form a broad synform. This area is bounded by the Quetico Gneiss Belt to the north and the Pukaskwa Gneiss Complex to the south and is intruded by numerous intrusive bodies (Figure 2.3 , Muir, 1983).

The local volcanic rocks have been divided into two groups; the Playter Harbour and Heron Bay groups. The Playter Harbour group consists of of iron-rich tholeiitic basalt flows and pillowed flows while the Heron Bay group consists of dacitic to rhyolitic calc-alkalic pyroclastic breccia and tuffs (Muir, 1983).

2:2:3 - Deposit Geology

Three formations are found within the vicinity of the camp: the Cedar Creek, the Moose Lake and the Rule Lake Formations.

The footwall Rule Lake Formation consists of intermediate to mafic tuffs interbedded with minor greywacke and arkose capped by a marker horizon of basalt. The Moose Lake Formation hosts the gold mineralization. This formation is composed of siltstones overlain by

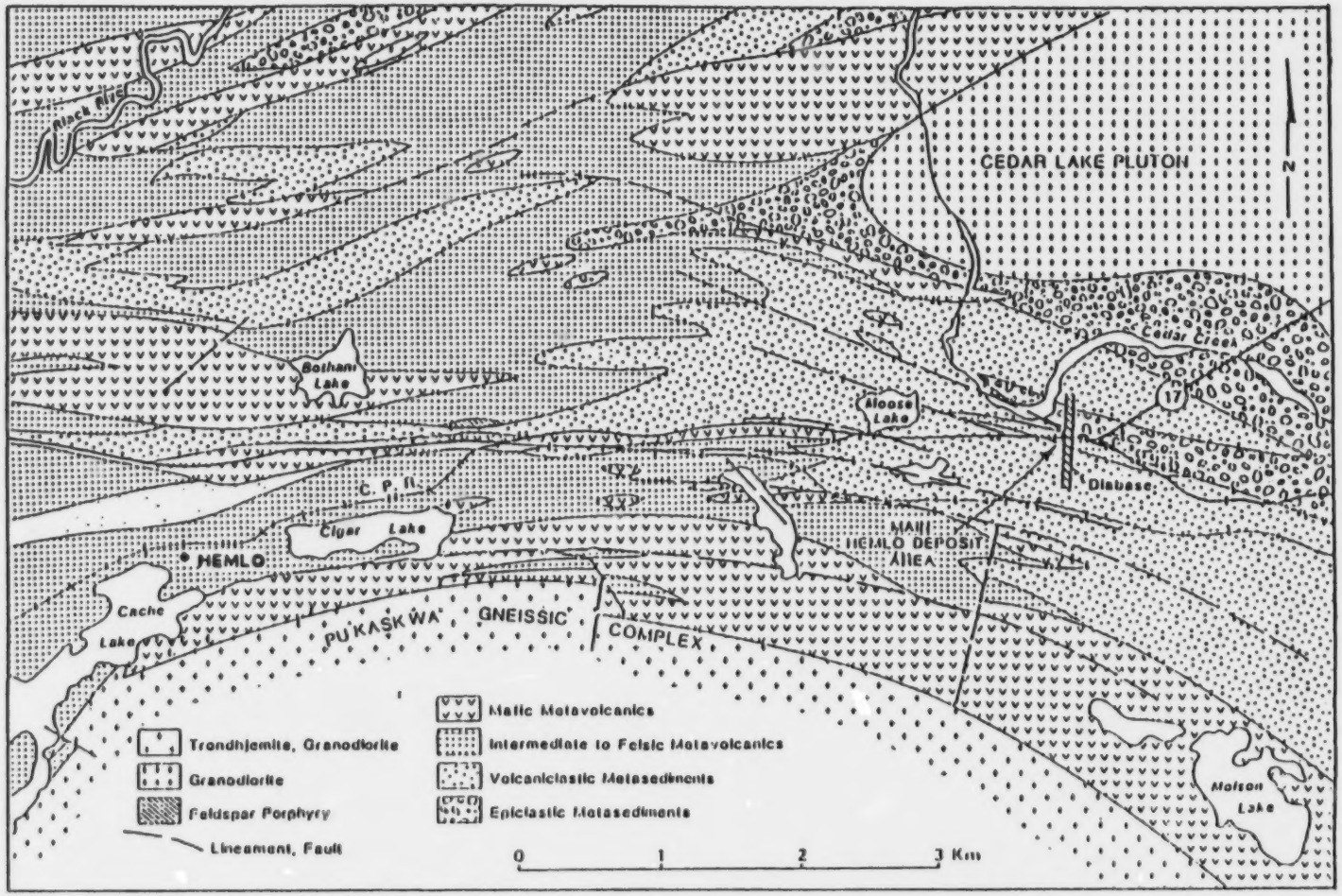


Figure 2.3 Simplified geology of the Hemlo area (from Muir, 1982).

a thick sequence of greywackes with felsic to intermediate volcanics towards the top. The hanging wall, Cedar Creek Formation, consists of coarse clastics, siltstones, pelites and wakes (Quartermain et al., 1983).

The mineralization occurs as fine grained gold associated with disseminated pyrite and molybdenite. Discrete gold grains, less than 250 µm in diameter occur at the edges of pyrite grains and molybdenite flakes and disseminated in quartz-feldspar rich layers (Quartermain et al., 1983).

2:2:4 - Quaternary Geology

The sediments, of late Wisconsinan age or younger, consists of numerous till facies throughout the area, ice-contact stratified drift and proglacial outwash in the east and a thick sequence of glaciolacustrine sediments in western basins. The predominance of ice-contact stratified drift and proglacial outwash indicates stagnation and ablation of the ice sheet (Geddes and Bajc, 1985).

Ice movement direction varies from 180 degrees azimuth in the eastern section to 240 degrees azimuth in the northwest corner. Geddes and Bajc (1985) state that the changes in the direction of ice movement is controlled by the bedrock topography and influence of the Lake Superior basin. Alternately, the presence of these two ice directions in the same area may indicate two separate glacial advances.

Within the camp a relatively sandy till overlies the deposit. In areas where the overburden is thicker, this semi-local till is overlain by an exotic calcareous silty till containing numerous

rounded Paleozoic clasts from the James Bay Lowlands (Geddes and Bajc, 1985).

The semi-local till that overlies the mineralization is an unsorted , oxidized rusty coloured sandy till. The till consists of approximately 40 % angular volcanic and sedimentary clasts of local derivation and 60 % sub-rounded to rounded granitic clasts derived from intrusive bodies to the north. The till also contains a minor component of Paleozoic clasts and fossils derived from the James Bay Lowlands.

In areas of good drainage the soils that have developed on these sandy acid tills are podzolic soils with Bf horizons up to 50 cm thick. An Ae (eluviated) horizon is well developed in some areas and absent in others. The humus layer is ubiquitous throughout the area.

In the poorly drained areas the presence of gleying and mottling are distinct characteristics of gleysolic soils. These soils are restricted to the valleys in an extremely undulating topography.

2:3 - Green Lake Showing

2:3:1 - Location

The Green Lake mineralization is located in Darling Township, of Lanark County of Southeastern Ontario (Figure 2.1). The area lies 1.7 km west from Hwy 511 at a point 15.4 km south of the bridge at Calabogie Village (Carter et al., 1980).

2:3:2 - Regional Geology

The area lies within the Hastings Basin which forms part of the central metasedimentary belt, of the Grenville Province. The

supracrustal rocks within the basin consist of mafic to intermediate metavolcanic rocks with interbedded metatuffs and carbonate sediments overlain by alternating sequences of clastic and carbonate metasedimentary rocks. Numerous plutonic rocks, ranging from mafic to felsic, have intruded the supracrustal rocks (Pauk, 1983; Gleeson et al., 1984).

The supracrustal rocks have been folded around north to north-northeast trending axes. The Robertson Lake Shear Zone, one of a series of northeasterly trending structures and lineaments passes through the research area extending 90 km to the south (Figure 2.4). Lithologies within this shear zone are highly altered and mineralized. The dominant alteration types are widespread chloritization and carbonatization and localized intense silicification (Pauk, 1983; Gleeson et al., 1984).

2:3:3 - Deposit Geology

The Green Lake showing is hosted by dolomitic marble which is bounded to the east and west by amphibolite. The mineralization is one of a series of nine showings extending 19 km along strike within this narrow belt of interbedded marbles and mafic volcanics (Carter et al., 1980).

The dolomitic marble is very fine grained , light to dark grey in colour and massive, to locally well layered, in structure. Numerous pods and lenses of medium to coarse grained white dolomite and quartz are present throughout the marble (Carter et al. 1980; Gleeson et al. 1984).

The gold mineralization is associated with disseminated blebs and streaks of tetrahedrite, pyrite and chalcopyrite which are

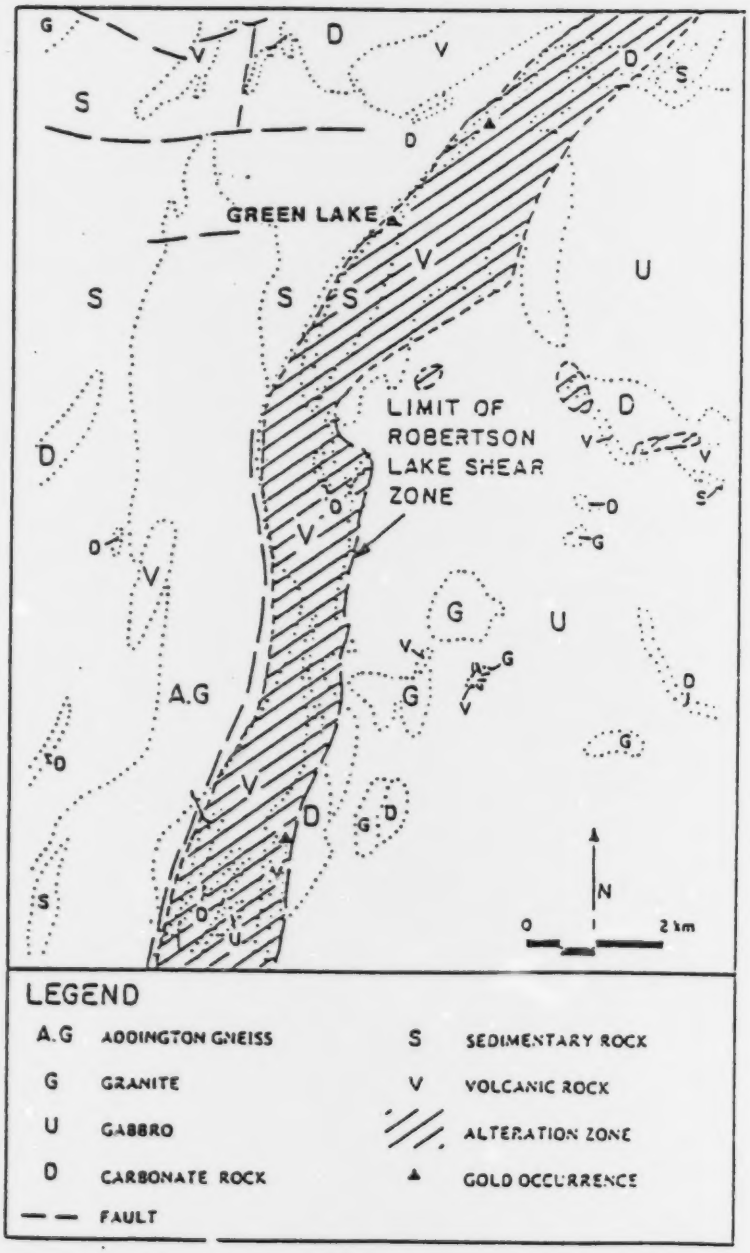


Figure 2.4 Simplified geology of the Green Lake area (from Gleeson, 1984).

confined to the white dolomite and quartz lenses and pods (Carter et al., 1980; Gleeson et al., 1984).

2:3:4 - Quaternary Geology

During the Late Wisconsinan period, the glacial ice movement, based on glacial striae, was in a southerly direction. Regionally, till is widespread throughout the area with glaciofluvial and deltaic sediments underlying some till facies in many locations (Gleeson et al., 1984).

This till, classified as ablation till, is loose to compact and is light brown in colour. The till varies in composition from a sandy till with a significant proportion (10 - 20 %) of coarse clasts to a stony till with pebble size and larger clasts constituting up to 35 % of the till (Gleeson et al., 1984). The till, even though considered an ablation till, has been successfully used as a sample media by Gleeson et al. (1984), because it contains locally derived material from the mineralization.

The area is located on a ridge covered by this local ablation till and is bounded to the east, west and north by glaciofluvial material. On the eastern flank of the ridge, the glaciofluvial sediments are underlain by a compacted, dark grey , sandy till which has been classified as a lodgement till. The till consists approximately 90 % volcanic clasts with only minor amounts of granitic and carbonate clasts. In contrast, the ablation till is composed of only 50 % volcanic clasts with 30 % carbonate and the rest granitic clasts.

The soil overlying the calcareous tills is a brown soil of the brunisolic order. In areas of glaciofluvial deposits and

non-calcareous tills podzolic soils have developed. All horizons of the soil profiles appear to be oxidized due to the percolating groundwaters (Gleeson et al., 1984).

2:4 - McBean Mine

2:4:1 - Location

The open pit of the McBean Mine lies just east of the town of Dobie, 10 kms east of Kirkland Lake, Ontario, along Hwy 66 (Figure 2.1). The mine is owned by Queenston Gold Mines and operated by Inco Ltd..

2:4:2 - Regional Geology

The Kirkland Lake area lies within Abitibi greenstone belt of the Superior Province. The bedrock geology consists of metasediments, metavolcanics and plutonic rocks (Figure 2.2). The volcanic succession is a series of volcanic cycles each composed of basal komatiitic rocks overlain by successive layers of tholeiitic and calc-alkalic rocks and capped by alkalic rocks. The metasediments are composed of turbidites, conglomerates, wackes, argillites, carbonates, chert and iron formations (Jensen, 1983).

An east-plunging synclinorium, 80 to 120 km wide, is intersected by the Porcupine-Destor Fault Zone on the northern limb and by the Kirkland Lake-Larder Lake Fault Zone on the southern limb, the latter fault zone passing through the McBean Mine (Jensen, 1983).

2:4:3 - Deposit Geology

The McBean Mine open pit is located right on the Kirkland Lake-Larder Lake Fault which is characterized by intense shearing and carbonitization.

The deposit is orientated east-west along the fault zone and is roughly egg-shaped with dimensions of 64 metres in length and 31 metres wide. The mineralization dies out to the east and west but appears to be open at depth.

The ore body is hosted by a syenite plug which is flanked to the north by talc-chlorite schist and highly schistose sediments and to the south by talc-chlorite schist and sheared volcanics and tuffs (Thomson and Griffis, 1941; Inco, internal report, 1984).

The mineralization consists of gold particles as inclusions in fine grained pyrite grains with minor amounts of disseminated discrete gold grains.

2:4:4 - Quaternary Geology

Based on bedrock glacial striae and pebble orientation, the direction of the last major Wisconsinan ice advance appears to be approximately 165 degrees azimuth. Regional work by Baker (1984), using similar features along with chattermarks, roche moutonee and crag and tail orientations noted a similar ice direction. Older striae of 200 degrees azimuth preserved in limited areas suggest an earlier advance while younger striae crosscutting the 165 degree azimuth striae indicate minor readvances (Baker, 1984).

Regionally, only one mappable till unit occurs throughout the Kirkland Lake area. Various till facies, ice-contact stratified drift, proglacial and aeolian deposits are present in the area (Baker, 1984). One of the most prominent features of the area is the Munro

esker which flanks the deposit to the west.

Within the McBean Mine pit , the south wall stratigraphy is topped by a sandy sequence belonging to the eastern flank of the Munro esker. Underlying the sands is a thick sequence of varved silts and clays with a basal layer of blue clays. Next, approximately 2 metres of till is present which is divided into an upper meltout facies, and a lower lodgement till. The sequence of glacial sediments was deposited in the lee of a roche moutonee which was formed by abrasion on the stoss side and plucking on the lee side of the bedrock high.

The lodgement till is a well compacted, calcareous, grey to buff coloured silty till. The clasts are mainly schists and mafic volcanics with 10 % granitic and 5 % syenite clasts. The till has a blocky structure and the clasts that are removed are clean with well preserved replica clasts remaining in the sediment.

2:5 - Summary

In summary, the four deposits studied provide a range of mineralogy and particle size of the gold. Namely, Owl Creek is characterized by both free gold with an average diameter of 100 um and pyrite-held gold varying in the size range 20 to 30 um (Scott, pers. comm., 1985). At Hemlo gold averages 15 um in diameter both as free gold and sulphide-held particles but varying from sub-micron up to 250 um (Carson, pers. comm., 1985). No information is available on the size of gold associated with the Green Lake showing (Lortie, pers. comm., 1985). At the McBean Mine, the majority of gold occurs in pyrite and in the size range 10 to 30 um (Pattison, pers. comm., 1985).

Chapter 3

Methods of Investigation

3:1 - Field Methods

Bulk till samples (> 50 kg) were collected from selected sites at each of the four study areas: Hemlo, Owl Creek, McBean Mine, and Green Lake showing. Samples weighed more than 50 kg to provide adequate material to conduct a series of tests.

At the Owl Creek and McBean Mine open pits and the Green Lake showing, sample sites were selected on the basis of which tills contained anomalous gold contents and because of the spatial relationship of these tills to mineralization with respect to ice movement. A similar approach was used at Green Lake.

Material from seven traverses was collected over the Hemlo deposit, three over the Golden Sceptre property and four over the Teck-Corona deposit. Samples of all horizons (Ae, B and C - mainly till) were collected to determine which horizons contained anomalous gold contents and subsequently to determine the extent of the dispersion train of mineralization caused by glacial processes. The samples were taken every 8 metres over the deposits, while down-ice and up-ice of the mineralization, the sample interval was progressively increased. The traverse generally ended 350 metres up-ice and 500 metres down-ice.

3:2 - Sample Preparation

3:2:1 - Wet Sieving

To determine the particle size distribution of the tills approximately 250 g of the minus 2 mm material was disaggregated by a mortar and pestle and then wet sieved. The sieve sizes used were: 2mm (9 mesh), 1mm (18 mesh), 500 µm (32 mesh), 250 µm (60 mesh), 125 µm (115 mesh) and 63 µm (250 mesh).

To test the reliability of disaggregating the samples by mortar and pestle, duplicates of two samples were also disaggregated by using a ultra-sonic vibrator. The samples were allowed to sit in the bath for one hour with frequent stirring. This method showed similar results to those obtained by mortar and pestle.

Heavy mineral concentrates of till samples were also wet sieved into the various particle sizes to determine the relationship of the particle size distribution of the heavy mineral concentrate to that of the bulk sample. (A description of the sample preparation is in Appendix A.)

3:2:2 - Sample Preparation For Analysis

Bulk samples were dried, disaggregated and sieved through a 63 µm sieve. Approximately 8 g of this fraction was placed in sample vials and sent to NAS for analysis. In certain cases, three 8 g aliquots of particular samples were sent for analyses in order to test the reproducibility of the gold analyses.

The various size fractions of the equivalent heavy mineral concentrates were placed in separate vials and sent for analysis.

3:2:3 - Gravity Concentrating Methods

3:2:3:1 - Separatory Table and Heavy Liquids

Heavy mineral concentrates examined during the project were prepared by processing laboratories operated by the following companies: Overburden Drilling Management Ltd., Assayers (Ontario) Ltd., and Kidd Creek Mines Ltd..

To clarify some of the terms used in the text of the thesis, the heavy mineral concentrating procedure is outlined in Figure 3.1. The procedure basically involves the removal of the plus 2 mm fraction of the sample, and passing the minus 2 mm fraction over a separatory table. In some cases wetting agents are used to reduce surface tension and to aid in the recovery of fine grained particles. The sample may also be passed over the separatory table more than once. Four fractions are produced; the non-magnetic heavy mineral concentrate, the magnetic heavy mineral concentrate, the heavy liquid-light fraction, and the table light fraction. A major proportion of the fine grained material is not recovered by the table but, is lost as table effluent. The heavy mineral concentrate from the table is then treated by heavy liquids, frequently methylene iodide (S.G.- 3.3) to further concentrate the heavy minerals. In some cases tetrabromoethane may be used (S.G.- 2.9) which allows for the recovery of slightly lighter minerals in the heavy mineral fraction and is thus suitable for the recovery of gold included in quartz or silicate grains. The heavy mineral concentrate produced from the heavy liquid separation is then divided into non-magnetic and magnetic

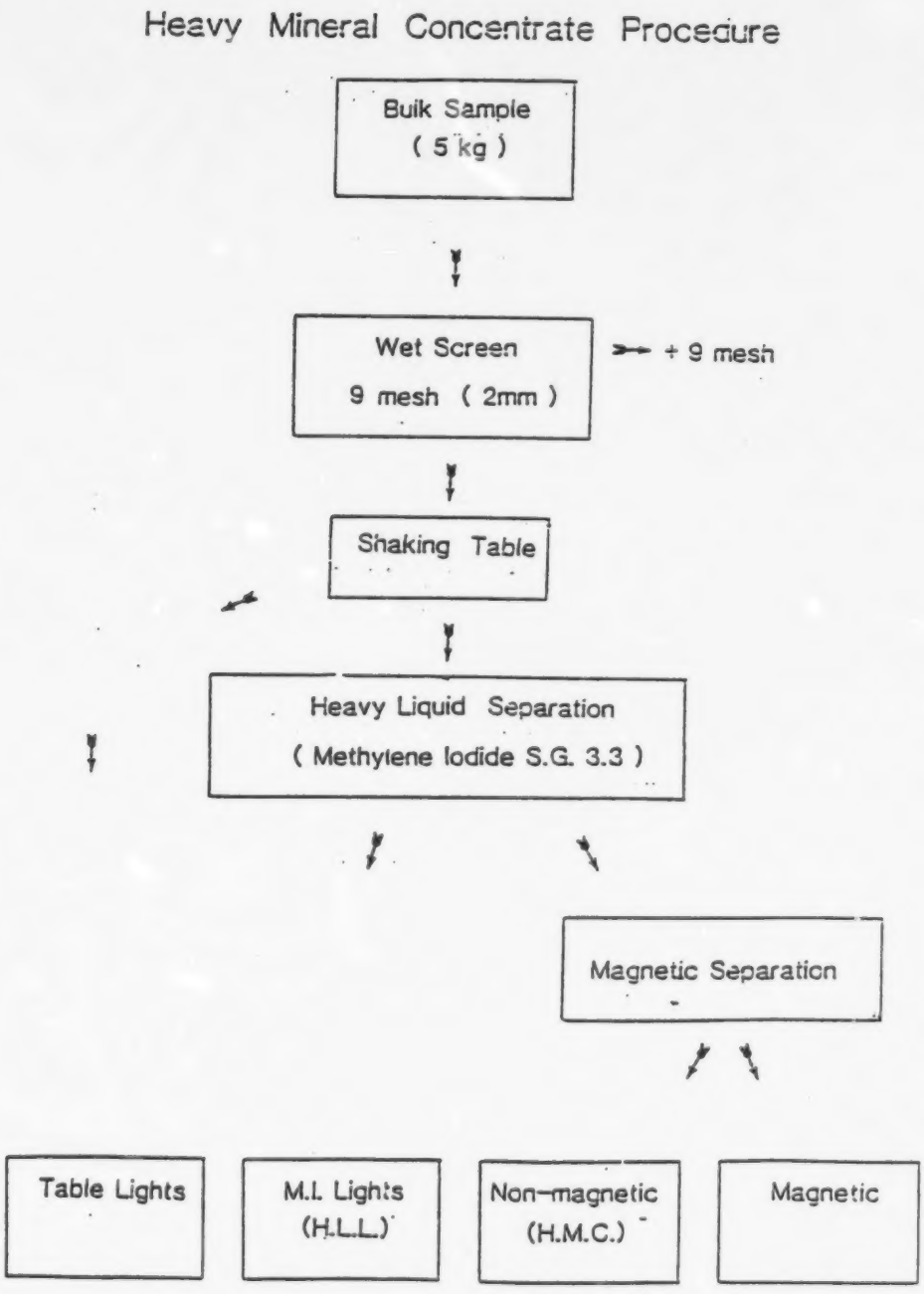


Figure 3.1 Flowsheet of the heavy mineral concentrating procedure.

fractions. Of the four fractions produced by the process, only the non-magnetic heavy mineral concentrate is analyzed in most geochemical exploration programmes except in situations where gold is thought to be associated with iron formations. In the current project, all fractions were analyzed in order to determine the absolute amount of gold in the original sample and to determine the proportion of the total gold being concentrated into the heavy mineral concentrate. Fine grained material of low specific gravity is lost from the table as effluent and no reliable data are available as to the amount of gold lost in this manner.

During processing, up to 45 % of the sample material is lost as table effluent. Consequently, gold particles suspended in the effluent are also lost. Therefore, calculation of the total gold content of the original sample based on analysis of the recovered fractions may be grossly underestimated.

3:2:3:2 - Wet Sieving and Heavy Liquid Technique

Heavy mineral concentrates prepared by this process were done by C.F. Minerals Ltd., Kelowna, B.C..

The system involves using a wet sieving technique consisting of a series of sieves submerged in water. The greater the number of sieves used, the more restricted is the individual particle size range. Three sieves were used for the preparation of samples for this project, with the corresponding particle size fractions being: minus 2000 plus 500 µm, minus 500 plus 125 µm and minus 125 µm. The material from each sieve was further separated by heavy liquids. To determine the amount of gold lost by using methylene iodide (S.G.=

3.3) instead of a heavy liquid with a somewhat lower specific gravity, the sieve fractions were treated by tetrabromoethane (S.G.=2.9) prior to treatment by methylene iodide. This procedure separated the samples into four fractions:

a) heavy mineral concentrate (S.G.> 3.3)

b) intermediate heavy mineral concentrate (S.G.> 2.9 < 3.3)

c) light fraction (S.G. < 2.9)

d) material in suspension

Utilizing this procedure, 90 to 99 % of the original sample is retained. Therefore, analysis of the returned sample fractions gives a reliable determination of the total gold content of the original sample.

3:2:4 - Cyclosizer

In order to determine the particle size distribution and the partitioning of gold in the minus 63 µm fraction of the tills, a Warman Equipment Ltd. cyclosizer was used. The equipment separates the material into fractions of equal hydraulic equivalence: for example, quartz spheres 44 to 63 µm in diameter will be classed with gold flakes 21 to 63 µm in diameter. The particle size of the various minerals in a class is determined by the specific gravity and their shape.

The cyclosizer consists of a series of five inverted cyclones (Figure 3.2). At the top of each cyclone is a collection cup from which the entrapped sample can be removed by operation of an adjoining valve. The diameter of the inter-connecting pipes are progressively

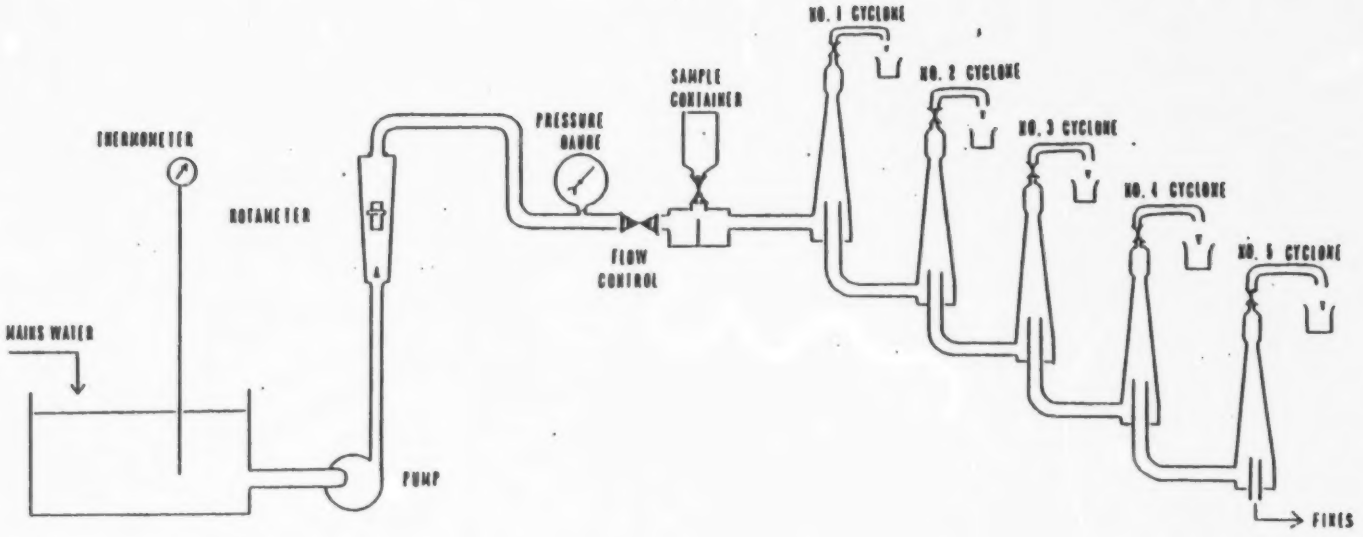


Figure 3.2 Illustration of the cyclosizer (from Sober,1985).

reduced, with the smallest pipe diameter between cyclone #4 and #5. This reduction in the pipe diameter leads to an increase in the inlet velocity and subsequently, an increase in the centrifugal forces within the cyclone so that particles of lower hydraulic equivalence are retained in each succeeding cyclone. The rate of the water flow through the equipment can be controlled by a valve mounted upstream of the series of cyclones. The valve was fully open during the study resulting in a flow rate of 11.6 litres per minute.

Approximately 300 g of the minus 63 um fraction of each till was processed in portions of 75 g each. This amount of material was needed in order to guarantee an adequate amount of material in each hydraulically equivalent fraction for analysis. The amount of material processed during each run is limited by the size of the sample collector cups. Once the cups are full, poor separation of the sample will result. For this study, the effluent from the cyclosizer was also collected to determine what proportion of the gold is present in the clay size material. All hydraulically equivalent factions were dried, placed in the sample vials, weighed, and subsequently sent for analyses.

To determine the particle sizes of the different minerals retained within a certain cyclone, the flow rate, water temperature, elutriation time and, most important, the specific gravity of each mineral, must be considered. Each factor will have a correction applied, the amount being dependent on the degree of deviation from the specifications for which the equipment was initially tested.

Before relying implicitly on gold data obtained on the fractions separated using the cyclosizer, the equipment was tested for the

possibility of cross contamination of samples. A gold-free silica sample was run before and after a sample anomalous in gold. Analysis of the various fractions of each silica run showed that gold was not present in either the silica run before or after the treatment of the anomalous sample. Based on this test, contamination was considered to be unlikely.

3.3 - Analytical Techniques

3:3:1 - Instrumental Neutron Activation Analysis

All samples were sent to Nuclear Activation Services (NAS) in Hamilton, Ontario for Instrumental Neutron Activation Analysis (INAA). A major advantage of INAA is that it is non-destructive and therefore the sample can be examined after irradiation.

A 5 megawatt pool type reactor located at McMaster University, Hamilton, Ontario, is used by Nuclear Activation Services Ltd. At the normal operating power of 2 megawatts, fluxes of 2×10^{13} thermal neutrons/cm^2 sec and 2×10^{12} epi-Cd neutrons/cm^2 sec permit simultaneous irradiation of many samples.

Instrumental neutron activation analysis (INAA) involves the irradiation of samples by a neutron flux, and the synthesis of radioactive isotopes. The intensity of the characteristic radiation of an isotope is a measure of the amount of the isotope, which, is directly proportional to the amount of the initial element. The most important nuclear reaction for INAA is "neutron capture" which involves the absorption of low energy neutrons (thermal neutrons: 0.025 eV) and the emission of gamma radiation (Chatt and Katz, 1980;

Dostal and Elson, 1980; Gibson and Jagam, 1980; Haskin, 1980; Hoffman et al., 1982).

The sensitivity of determination for a certain element depends on the number of atoms of that element that must be present in the sample to provide enough detectable and identifiable radiation from the daughter isotope. This feature is dependent on the following factors: a) the neutron flux or bombardment intensity; b) the cross-section, or the probability that a parent isotope will absorb a neutron; c) duration of neutron irradiation; d) the efficiency of the radiation detector; e) ease of detecting the radiation emissions and f) the half life of the daughter isotope. To eliminate montoring all of the above factors, standards of known concentrations are inserted with the samples. This results in a simple proportionality between the amount of element in the sample and standard and the number of counts observed for each per unit time on the detector (Haskin, 1980).

When the samples are removed, the activities of the various isotopes will depend on the cooling time (the time from the end of irradiation until reading). The half life of the isotopes determines the cooling and irradiation times. For example, if the half life of the isotope is shorter than that of interfering isotopes then a shorter irradiation time is used; conversely, if the half life is longer then a longer cooling time is required (Dostal and Elson,1980; Gibson and Jagam, 1980).

The gamma radiation emitted by the various isotopes is detected by a germanium-lithium detector. With a multichannel analyzer and the associated computer equipment, as many as 35 elements can be detected in a small sample (Gibson Jagam, 1980; Hoffman et al., 1982).

Sources of error are: a) sample inhomogeneity, b) laboratory contamination, c) a non-uniform neutron flux, d) improper standards, e) timing and placing of samples relative to the detector, and f) consistent unknown interference from another activation product (Laul, 1979; Gibson and Jagam, 1980).

Advantages of the technique are: a) a reduced chance of contamination since no chemical stages are involved and the number of handling stages is less than other methods, b) the reduction in handling and analytical time due to multi-element analysis on a single sample, c) the ability to analyze a large number of samples, d) acceptable detection limits for all elements analyzed, and e) non-destructive analysis allowing for future examination of the sample.

In the this project, the sample were irradiated for one hour. Following irradiation, the samples were allowed to decay for 3.5 days before being read by the detector for 200 seconds. The half-life for ^{198}Au is 64.8 hours and the characteristic radiation energy is 411.8 keV.

3:4 - Data Quality

Before any analytical data can be evaluated reliably, the quality of the data must be considered. Two aspects of quality control are examined: a) the precision and accuracy of the analytical data, and b) the representativeness of the samples.

3:4:1 - Methods of Analytical Quality Control

In order to determine the precision and accuracy, reference materials of a known metal content were inserted throughout the batch, at a frequency of one reference sample every ten to twenty samples. If possible, these reference materials should be similar in particle size, chemical composition, and mineralogy to the samples being analyzed, in order that the reference materials will behave like the samples during analysis.

Precision is a measure of the variability of repeat analyses, and is defined here as the percentage range at the 95 % confidence limit or two relative standard deviations (2RSD) of the repeat measurements. Accuracy is the difference between the measured value and the true value. The accuracy is very important when comparing data from different batches.

3:4:2 - Precision and Accuracy

During the course of the programme, three reference materials were used; SARM 7, CCU-1 and MA-2. The latter two reference materials were only submitted in two batches, while SARM 7 was inserted into every batch. Since SARM 7 was used throughout the program, the precision and accuracy will be examined using results obtained on this reference material. SARM 7 is a reference material from South Africa and is distributed by The South African Bureau of Standards. The standard consists mainly of a felspathic pyroxenite. Approximately, 96 % of the reference material is less than 75 µm in size and 66 % is less than 37 µm in size. The bulk matrix of the material is less than ideal for the samples being analyzed; however, it was the only reference material available at the time. The recommended value for

SARM 7 is 310 ppb which is suitable for the concentrations found in the bulk minus 63 µm samples but not for the concentrations present in the heavy mineral concentrate fractions.

The precision and accuracy as derived from all the analytical batches is shown on Table 3.1.

Table 3.1 - Precision and accuracy amongst batches

Sample	N	Mean	Std. Dev.	2RSD (95 % C.L.)	Accuracy
SARM 7	53	295	68 ppb	± 46 %	- 5 %

The precision for all batches is ± 46 % at the 95 % confidence level while the accuracy is excellent (- 5 % error).

However, an examination of the precision and accuracy of individual batches can show a far superior level of precision within a batch, for example ± 16 % at the 95 % confidence level (Table 3.2). The accuracy varied from batch to batch. For example, the worst cases were -39 % for Batch 23 and +42 % for Batch 16. These shifts in accuracy were considered when comparing data from different batches by adjusting the the accuracy of each batch to zero prior to comparing the data . In summary, these shifts in accuracy are undesirable, the cause is unknown at this time, and this effect must be monitored throughout a project

Subsequently, the samples of SARM 7 from batches 14, 15, 16, and 20 were reanalyzed in one batch, batch 26 (Table 3.2). The precision of this batch is ± 42 % at the 95 % confidence limit and the accuracy

Table 3.2 - Precision and accuracy of various batches

Batch No.	N	Mean	Std. Dev. (ppb)	2RSD %	Accuracy %
6	2	295	50	± 34	- 3
7	3	287	6	± 4	- 7
10	6	250	24	± 20	- 19
11	2	285	21	± 14	- 8
12	2	255	7	± 6	- 18
13	4	268	29	± 22	- 14
14	6	220	30	± 26	- 29
15	6	320	58	± 36	+ 3
16	3	440	104	± 48	+ 42
18	2	300	28	± 18	- 3
19	10	335	27	± 16	+ 8
20	4	255	50	± 40	- 18
22	3	243	67	± 54	- 22
23	2	190	0	± 0	- 39
26	20	287	60	± 42	- 7
26-14*	6	294	51	± 34	- 5
26-15	6	273	38	± 28	- 12
26-16	3	317	99	± 62	+ 2
26-20	4	280	74	± 52	- 10

* - subset of batch 26 equivalent to batch 14 etc. of original analyses

is -7 %. However, the accuracy of the individual batches within batch 26 is much better than the original analysis in three cases out of four. For example, the accuracy of the individual batches ranges from +2 to -12 % compared to -49 to +42 % for the original analysis. This improvement in accuracy is regarded as being related to inter-batch analytical inaccuracy. A remaining concern is the accuracy of the different batches.

3:4:3 - Representativeness of gold as a function of particle size

The repeatability of gold analyses when dealing with relatively coarse grained sample material is a major concern. In order to determine the gold distribution in the tills, the tills were divided into various size fractions. To demonstrate the repeatability of the gold analyses of the various size fractions, the minus 75 µm material was separated into six hydraulically equivalent fractions. Four of these fractions were selected to be analyzed a minimum of four times.

The results clearly demonstrate the problems that arise when trying to reproduce gold analyses from material with a quartz particle size range from 44 to 75 µm and an average of 60 µm (Figure 3.3). Therefore, the finer the material sampled and consequently the finer the gold grains, the more representative a sample of a given weight will be.

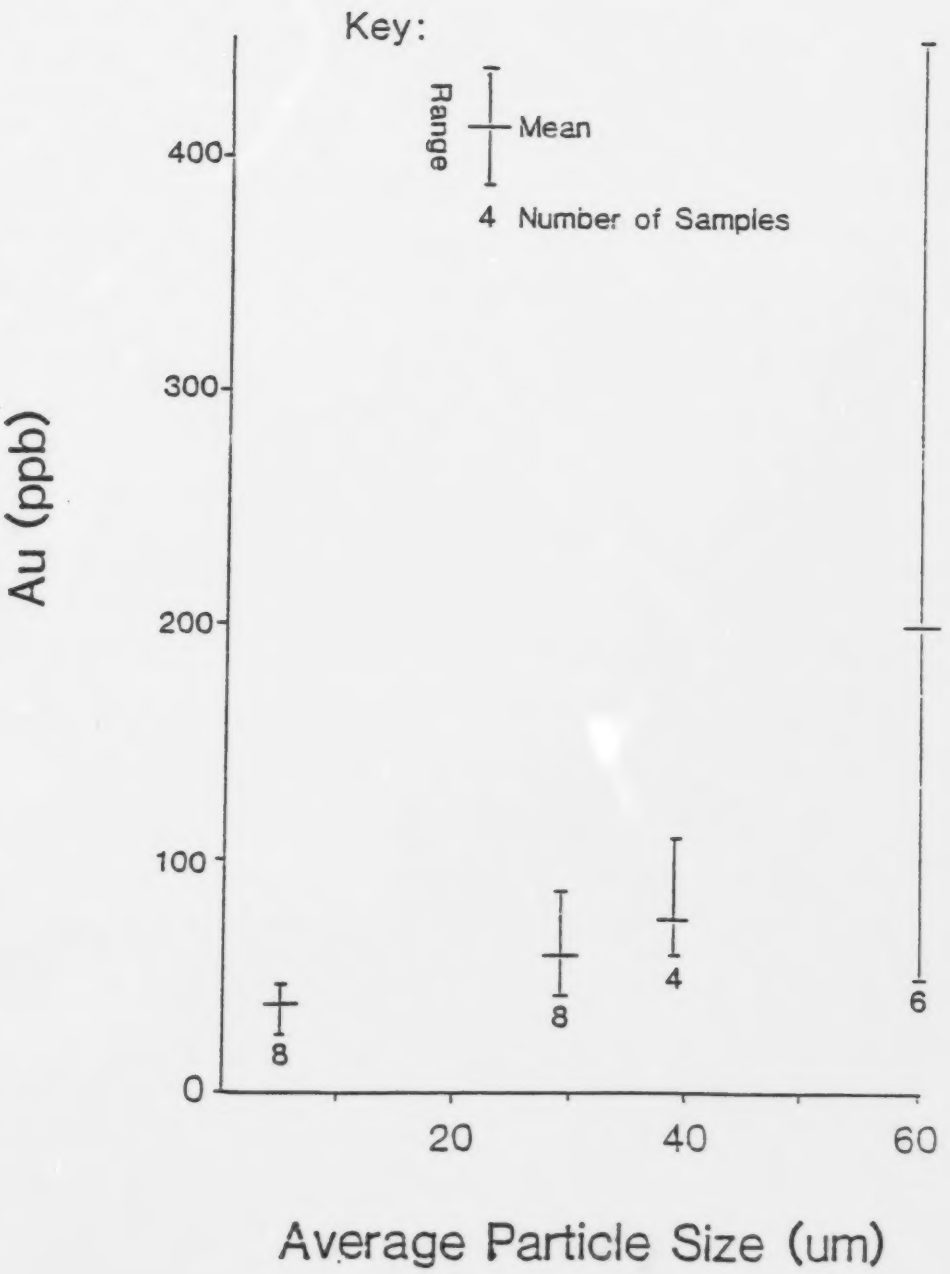


Figure 3.3 Representativeness of the gold in different size fractions of sample #5.

Chapter 4

Results and Discussion

This chapter consists of a presentation and a discussion of results. The different aspects discussed are as follows: 1) the particle size distribution of bulk till samples and heavy mineral concentrates obtained from these tills, 2) a comparison of gold contents of the heavy mineral concentrates and other fractions of the original samples, 3) the efficiency of the separatory process, 4) the distribution of gold in heavy mineral concentrates and heavy liquid light fractions, 5) the significance of "Concentration Factor", 6) a comparison of results obtained on heavy mineral concentrates processed by different laboratories and by different concentrating processes, 7) the distribution of gold in the minus 63 µm fraction of tills, and, 8) a comparison of gold data obtained on heavy mineral concentrates to that obtained on the minus 63 µm fraction. The gold data are listed in Appendix C.

4:1 - Particle Size Distribution of Bulk Till Samples

The silt and clay fraction (minus 63 µm) constitutes a major portion of the till, varying from 20 to 50 % of the minus 2 mm material (Figure 4.1).

4:2 - Heavy Mineral Concentrates (Gravity table)

4:2:1 - Particle Size Distribution

A grain size analysis of heavy mineral concentrates indicates a predominance of material in the minus 500 µm to plus 63 µm size range, with less than 10 % of the concentrate consisting of silt and clay sized material (Figure 4.1).

The heavy mineral concentrates have less silt and clay than do the bulk samples (Figure 4.1), indicating that the tabling process produces a concentrate biased toward the intermediate grain sized material.

4:2:2 - Comparison of Gold Contents of the Heavy Mineral Concentrates and the Heavy Liquid Light Fraction

Gold data obtained on the heavy mineral concentrates and the heavy liquid lights of till samples is shown in Table 4.1. Treating the data in the conventional manner, there appears to be a preferential concentration of gold in the heavy mineral fraction (HMC) relative to that in the heavy liquid light (HLL) fraction. The contrast between the two fractions varyies from 33 to 105 fold.

4:2:3 - Efficiency of the Separatory Process

The total gold content of the original sample was determined from the gold contained in the non-magnetic heavy mineral , the magnetic heavy mineral, the heavy liquid light and the table light fractions (Appendix D). The calculation does not include the gold

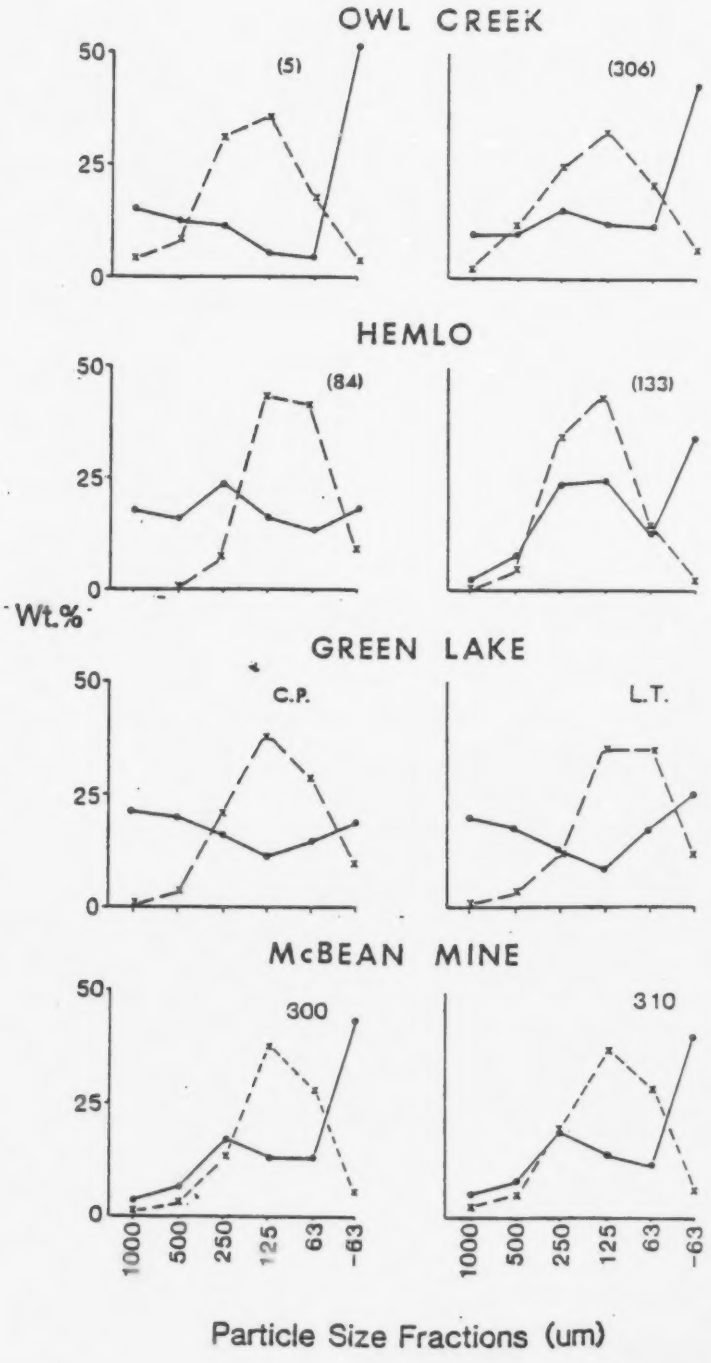


Figure 4.1 Variations in the grain size analyses of the bulk till samples to that of the heavy mineral concentrates of these samples from Owl Creek, Hemlo, Green Lake and McBean Mine.

Table 4.1 Variations in the concentration of gold between heavy mineral concentrates and heavy liquid light mineral fractions.

Sample No.	HMC (Au-ppb)	HLL (Au-ppb)	Contrast
5	5570	53	105
306	137060	1977	69
84	2828	86	33
133	9026	258	35
C.P.	1040	33	32
L.T.	310	7	44
300	587	12	50
310	724	17	43

Key: HMC - heavy mineral concentrate
HLL - heavy liquid lights
Contrast - ratio of gold content of HMC to HLL.

lost in the effluent from the separatory table. In all samples less than 15 % of the total gold has been concentrated into the non-magnetic heavy mineral concentrate (Figure 4.2). The vast majority of the gold is left in fractions other than the non-magnetic heavy mineral fraction. An additional feature is that the proportion of the gold being recovered in the non-magnetic heavy mineral fraction varies from 4 to 15 % of the total gold, indicating that the gold content of the non-magnetic heavy mineral fraction also bears a variable relationship to the total gold content of the original sample (Figure 4.2).

The efficiency of the heavy liquid separation to separate different size fractions was evaluated by determining the gold content of the various size fractions of both the non-magnetic heavy mineral and the heavy liquid light fractions. In the case of sample #5 (a silty to clayey, well compacted, unoxidized till), the heavy liquid separation of the table concentrate is very effective in the intermediate to coarse fractions, and there is a pronounced enhancement of gold in the non-magnetic heavy mineral fraction (Figure 4.3). On the other hand, in the finest fraction (minus 63 µm) comparable gold contents are apparent in the non-magnetic mineral fraction and the heavy liquid light fraction.

In comparison, sample #306 from Owl Creek is a loosely compacted, silty, oxidized till. A 100-fold contrast exist between the gold content of the non-magnetic heavy mineral concentrate and the heavy liquid light fraction. However, the heavy liquid light fraction contains more than 1000 ppb indicating that a considerable amount of gold remains in the heavy liquid light fraction (Fig.4.3). In

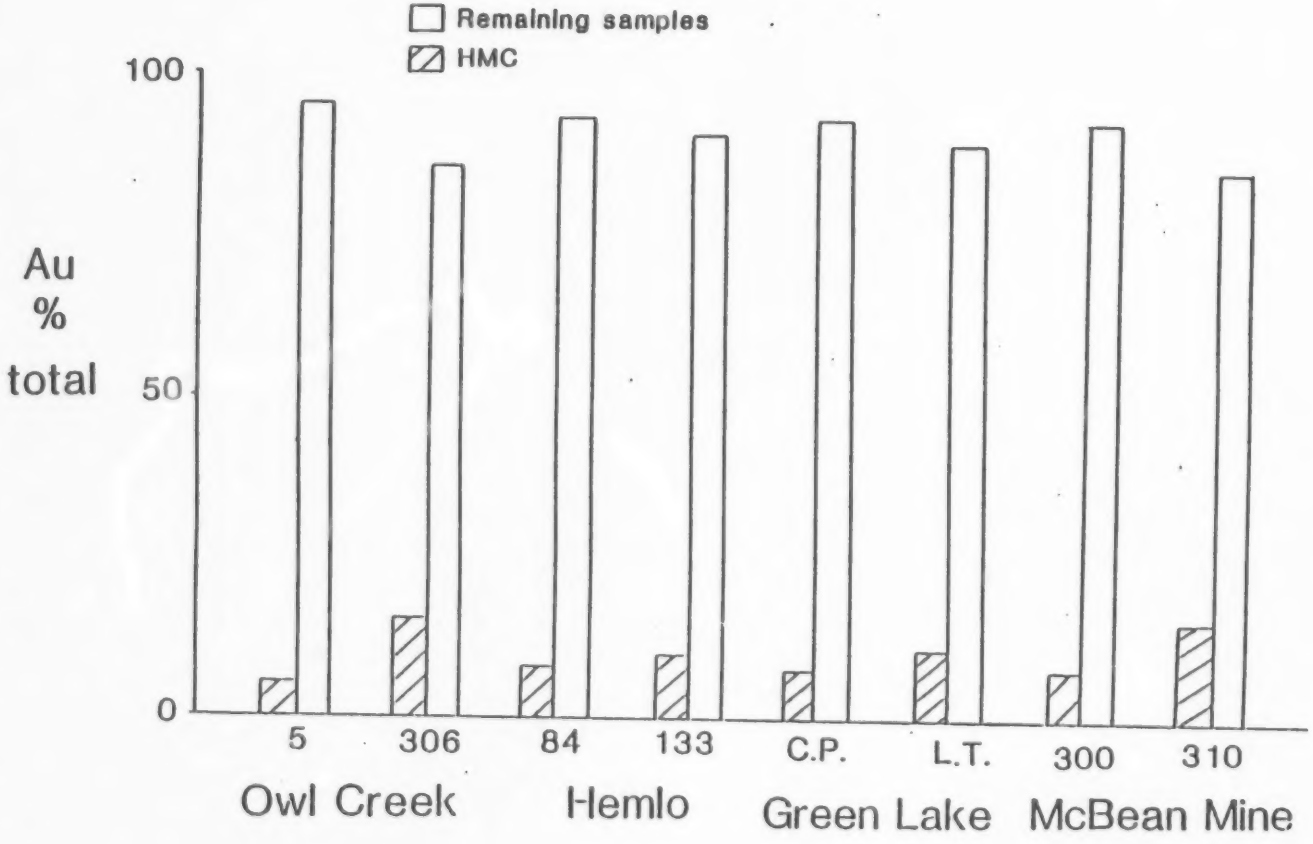


Figure 4.2 Partitioning of gold between the heavy mineral concentrate and the bulk till sample.

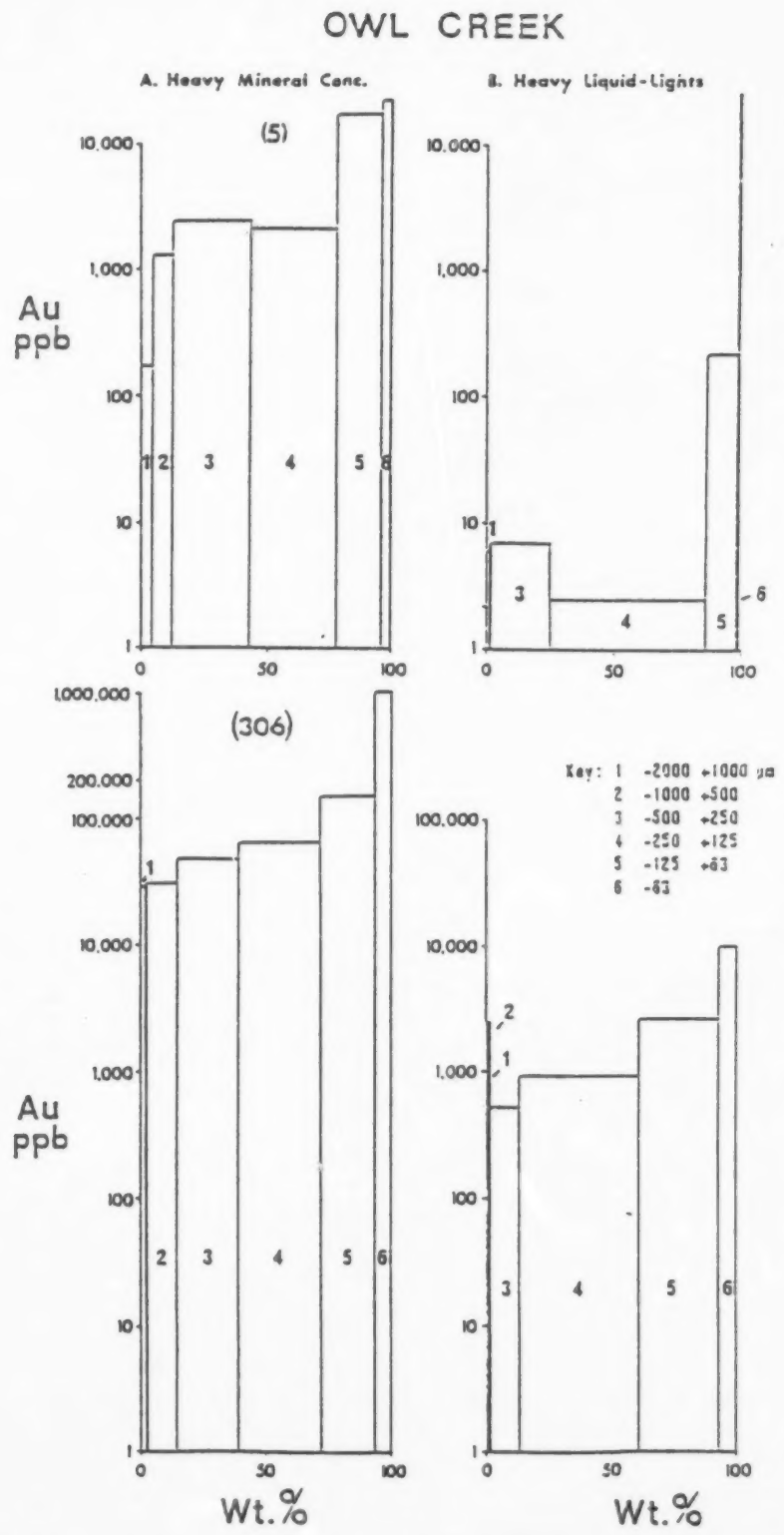


Figure 4:3 Variation of the gold content with a particular size fraction in the heavy mineral concentrate and the heavy liquid-light fractions of samples from Owl Creek.

addition there does not appear to be any marked variation in separation efficiency with grain size.

The study was extended to tills from Hemlo, Green Lake and McBean Mine. Anomalous gold contents are present in the heavy liquid light fraction of the oxidized tills from each property but not in the unoxidized tills from Green Lake or the McBean Mine (Appendix E).

In summary, the efficiency of the heavy liquid separation in terms of the grain size of tills associated with a single deposit type is variable. Also, the efficiency of the separatory process may be related to the degree of oxidation of the till and to the mineralogical mode of occurrence of the gold in the different tills.

4:2:4 - Mineralogical Mode of Occurrence of the Gold

As described previously, results indicate that in some cases significant concentrations of gold may remain in the fractions other than the non-magnetic heavy mineral fraction. For example, approximately 2000 ppb remain in both the heavy liquid lights and table lights of sample #306. The reason for this shortcoming could have been attributed to the fact that the form of the gold in the two fractions was different and that the concentrating procedure discriminated between different forms. A preliminary examination by Dr. J.D. Scott of Kidd Creek Mines, using a binocular microscope, showed that the gold is of the same mineralogy (free gold), size and shape within equivalent size fractions of the non-magnetic heavy mineral concentrate and the heavy liquid light fraction of sample #306. At this stage it is not known whether free gold accounts for

all the gold in the heavy liquid light fraction. If the mineralogy of the gold in the table lights is the same as the gold in the concentrate then further questions must be raised concerning the reliability of the separatory table as a concentrating method.

4:2:5 - Size Analyses

The different size fractions of the heavy mineral concentrates were analyzed to determine the size distribution of gold in different fractions. The weight of the gold in individual size fractions of the non-magnetic heavy mineral concentrates is determined on the basis of the gold concentration and the weight of the size fraction. Greater than 90 % of the gold present in the concentrate is found in the minus 500 µm fraction. In all samples except sample #310 (McBean Mine), the majority of this gold occurs in the minus 125 µm fraction. In sample #310, the majority of the gold is present in the minus 500 µm to plus 63 µm fraction (Figure 4.4a,b). (Sample #310 was collected immediately down-ice from the McBean deposit and it was assumed that any gold in the sample was derived from the McBean mineralization. Sample #310 is not anomalous in gold. The mineralization occurs in a low in the bedrock-till interface and was probably not eroded by the latest glacial advance. Consequently, material from the mineralization was not incorporated into the overlying till. Therefore gold present in the sediments was derived from another source up-ice of the McBean deposit.)

It appears from these results that a considerable proportion of the total gold occurs in the finer size ranges as concentrated by the table, but, in fact, only a small proportion of the total gold in the

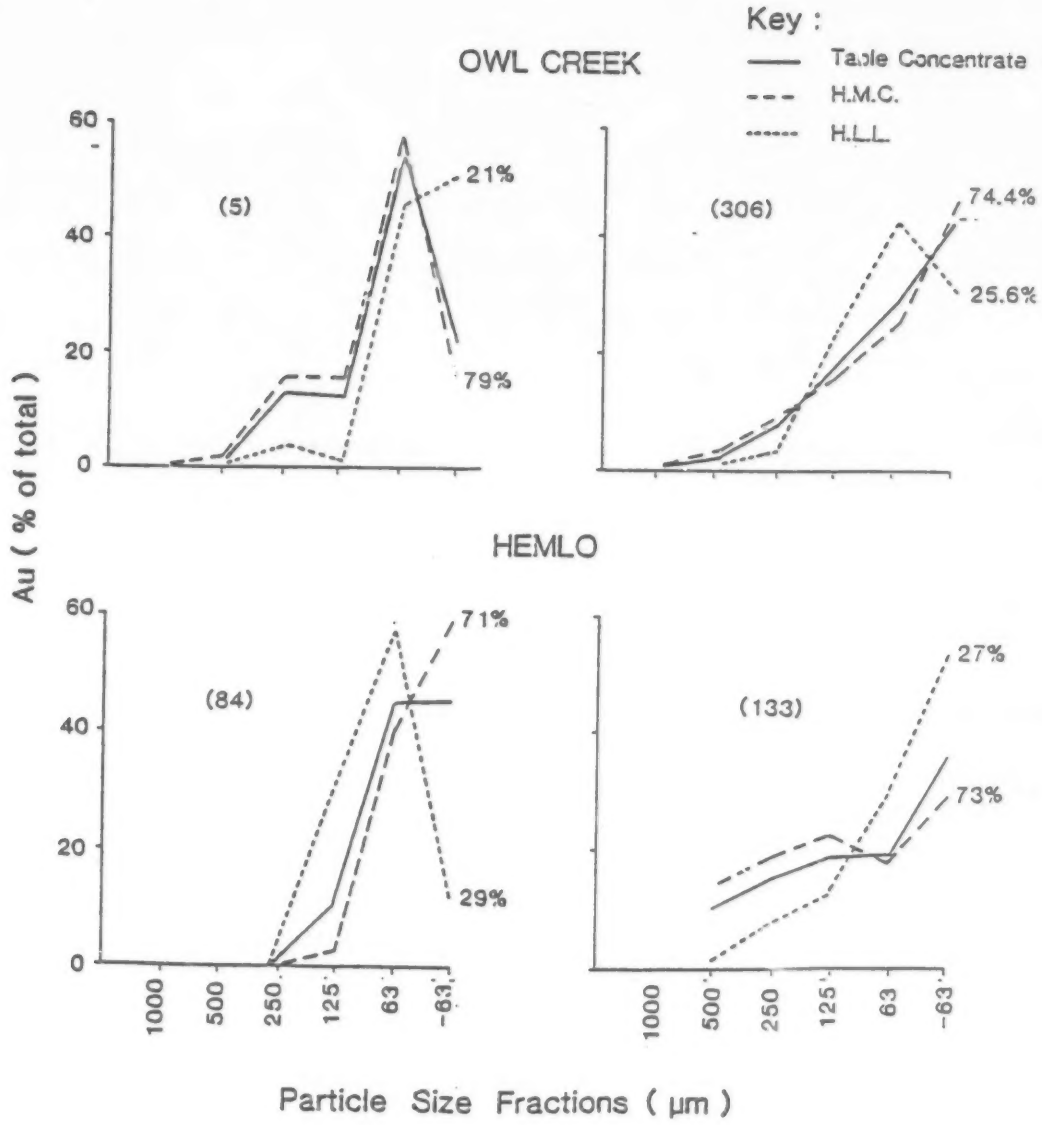


Figure 4.4a Variation of the gold content with grain size in the heavy mineral concentrates obtained from the tills collected at Owl Creek and Hemlo.

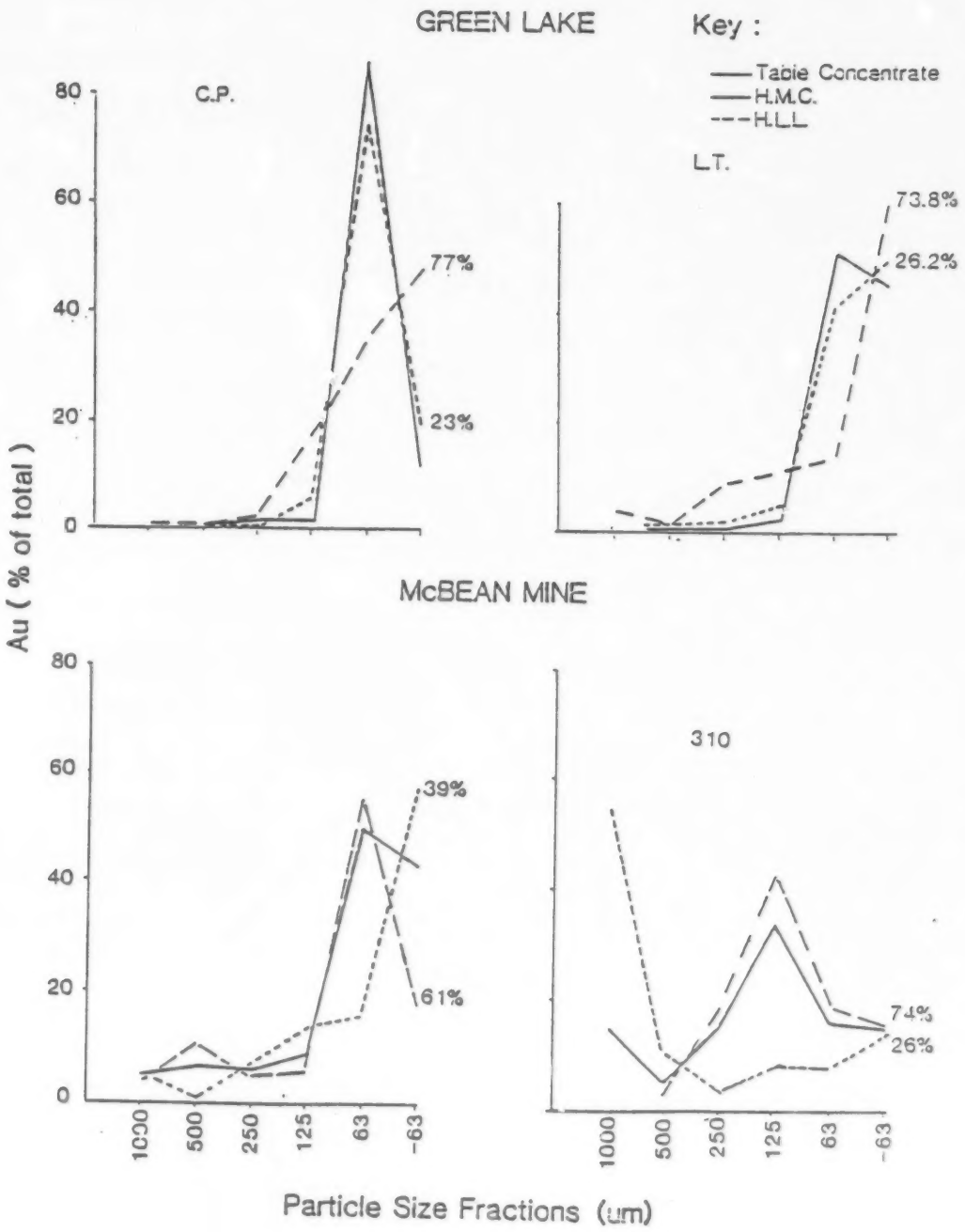


Figure 4.4b Variation of the gold content with grain size in the heavy mineral concentrates obtained from the tills collected at Green Lake and McBean Mine.

fine fraction is concentrated by the table. For example, the calculated amount of gold present in the minus 63 µm fraction of the heavy mineral concentrates represents only 6 ± 5 % of the total gold in that fraction of the original till samples. This feature draws attention to the fundamental limitation of the separatory table to quantitatively separate fine-grained material (Wang and Poling, 1983). The separatory table only recovers a small proportion of the gold in the size range in which the majority of the gold in the samples used in this study occurs (Figure 4.5). This work supports the conclusions drawn as to the efficiency of the table.

The partitioning of gold between the non-magnetic heavy mineral and heavy liquid light fractions shows that 75 ± 4 % of the gold in the table concentrate is partitioned into the non-magnetic heavy mineral fraction, except in the case of sample # 300 (again from the McBean Mine). In sample #300, only 60 % of the gold has been concentrated into non-magnetic heavy mineral fraction (Figure 4.4). By evaluating the efficiency of the heavy liquid separation using the absolute weight of gold, the results show a constant efficiency.

Since very little gold is present in the plus 500 µm fraction, the efficiency of the table may be improved by restricting the table feed to material of a size fraction less than 500 µm and therefore optimize the tabling conditions for the recovery of fine-grained gold. As discussed previously, a significant improvement in the percentage of gold recovered can be achieved by restricting the feed to a narrower particle size range (Poling, pers. comm., 1985).

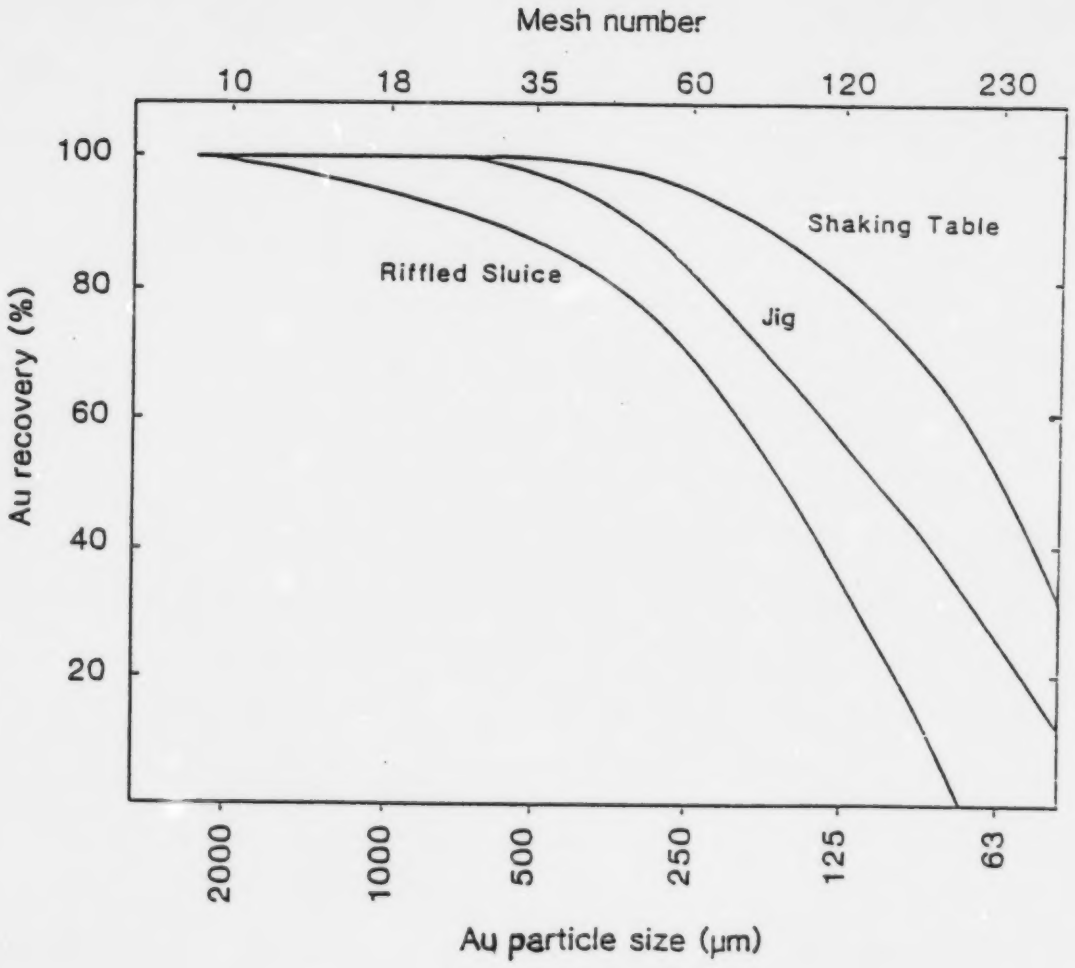


Figure 4.5 Variation in the percentage gold recovered with gold particle size (from Wang and Poling, 1983).

4:2:6 - Concentration Factor

The comparison of gold concentrations is the conventional method of interpretating heavy mineral concentrate gold data. The shortcomings of this approach are demonstrated by the following example.

The concentration factor is the ratio of the initial weight of the minus 2 mm fraction of the till to the weight of the non-magnetic heavy mineral concentrate. Consider first two hypothetical gold deposits, A and B, each of equal economic importance and of identical gold content in the surrounding tills (Figure 4.6). In situation A, the till is heavy mineral-poor, due to the relative absence of heavy minerals in the country rock or the mineralization. Upon processing of a 4.5 kg till sample, only 2.14 g of non-magnetic heavy mineral concentrate is produced resulting in a concentration factor of 2100. In contrast, in situation B the till is heavy mineral-rich and produces 15 g of non-magnetic heavy mineral concentrate. This results in a concentration factor of 300. Assuming that the table is either one hundred percent efficient, or that it consistently collects a certain percentage of the gold, then equal amounts of gold should be present in both concentrates. Analysis of the concentrates reveals a concentration of 7000 and 1000 ppb for tills A and B respectively. If a threshold of 2500 ppb was accepted, as is a common practice in the Canadian Shield, then the area of Sample A will be examined further but that of Sample B will not. Therefore, in view of the widely differing weights of heavy mineral concentrates obtained, it is more meaningful to consider the total gold content of the heavy mineral

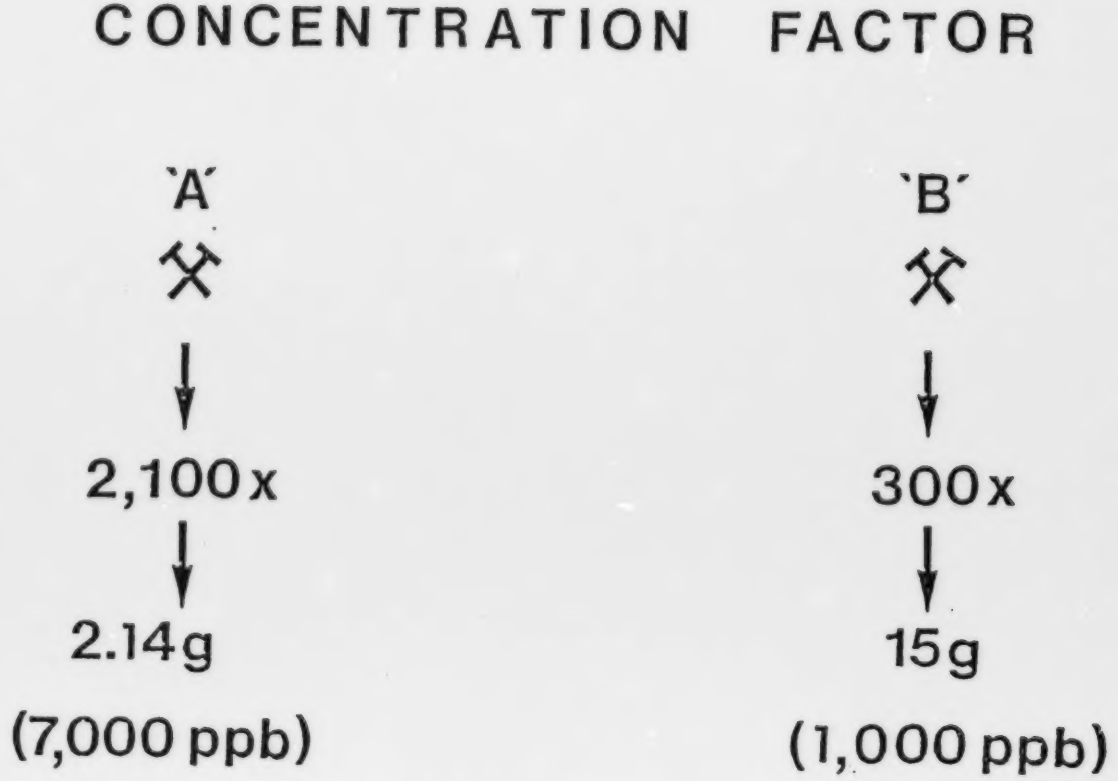


Figure 4.6 An illustration of the effects of Concentration Factor.

fraction, expressed as a weight of gold per standard weight of sample. For example, actual results show that concentrations of heavy mineral concentrate fractions of two samples are 8651 and 7346 ppb (Table 4.2) In this situation they would be considered to be of equivalent exploration significance. However, considering the fact that the weight of the heavy mineral concentrate from the second sample is twice that of the first sample, the total gold in the second sample is two-fold higher than that of the first sample and therefore presumably of greater economic significance.

The concentration factor for samples treated in this programme range from a minimum of 127 to a maximum of 4500.

4:2:7 - Inter-Laboratory Comparison

4:2:7:1 - Separation Efficiency

In order to evaluate and compare the efficiencies of the concentrating process, portions of each of two samples were sent to three laboratories which employ similar gravity concentrating technique involving the separatory table and heavy liquids.

A comparison of the results shows marked differences to exist(Table 4.3). For example, the concentration of gold in sample #5 recovered by Laboratory 3 is 26 to 54 times higher than Laboratories 1 and 2, repectively. In the case of sample #306, Laboratory 3 again recovers the greatest concentrations but in this case they are only two and three times higher than Laboratories 2 and 1, respectively.

As stated before, common practice involves evaluation of the gold data based on the concentration of gold in the heavy mineral

Table 4.2. Relation between gold concentration, heavy mineral concentrate weight and total contained gold of heavy mineral concentrates.

	Sample #5	Sample #133
Au in HMC (ppb)	8651	7346
Wt. of HMC (g)	8.4	20.1
Wt. of Au in HMC (ng)	72,666	147,645

Table 4.3 Comparison of gold contents of heavy mineral concentrates of samples prepared by three laboratories.

		Laboratory		
		1	2	3
Au in HMC of sample #5	Conc'n (ppb)	2,657	5,570	143,337
	Wt.(g) of HMC	7.1	2.9	4.4
	* Wt. (ng)	18,853	16,153	626,044
Au in HMC of sample #306	Conc'n (ppb)	77,598	137,060	258,018
	Wt.(g) of HMC	9.9	11.2	1.9
	* Wt. (ng)	765,706	1,535,072	493,793

* The weight of gold is equal to the concentration of gold times the weight of the heavy mineral concentrate.

concentrate. Based on gold concentration, the samples processed by Laboratory 3 would be considered the most significant, followed by Laboratory 2, then Laboratory 1. Now, if the evaluation is based on the actual amount of gold (i.e., gold concentration times the weight of the heavy mineral concentrate), expressed in nanograms (ng = 10^{-9}g), the order of significance, in the case of sample #5, is Laboratories 3, 1 and 2. In the case of sample #306 the order of significance is Laboratory 2, 1 and 3. Therefore, the evaluation of gold data based on the amount of gold is a truer representation of the data.

In order to examine the inter-laboratory differences further, two samples were selected for further testing. The samples were cone and quartered in an attempt to reduce the effect of sample heterogeneity. Five kilogram portions of each sample were sent to Laboratories 2 and 3.

Analyses of the heavy mineral concentrates obtained from sample #5 show over a thirty fold variation in both the concentration of gold in the heavy mineral concentrates and the total gold recovered (Table 4.4). Laboratory 3 recovers 209,479 ng compared to 6,655 ng by Laboratory 2. In the case of sample #223, Laboratory 3 collects 149,679 ng compared to 103,714 ng collected by Laboratory 2.

Considering the total amount of gold present in the original sample, sample #5, less that lost in the effluent, the sample processed by Laboratory 3 contains seven times more gold than Laboratory 2.

4:2:7:2 - Size Analyses

The majority of the gold in the heavy mineral concentrates of samples #5 and #223 as determined by Laboratory 2 is found in the minus 125 µm size fraction, whereas the majority of the gold present in the concentrates from Laboratory 3 is found in the minus 500 to plus 250 µm fraction (Figure 4.7). In both cases, there appears to be considerable differences in the size of gold particles being recovered by the two laboratories and Laboratory 2 is losing coarse-grained gold.

The absolute amounts of gold in the minus 63 µm fraction of heavy mineral concentrates of a specific sample produced by different laboratories is broadly similar (Table 4.4). However, the amount of gold in the minus 500 to plus 250 µm fraction varies in accordance with the laboratory used. Laboratory 3 recovers a considerably higher amount of gold than Laboratory 2. This discrepancy cannot be explained by the 'nugget effect' (ie. the effect of one or two coarse gold particles) because the pattern of coarse gold particles is noted in both the heavy liquid heavy and the heavy liquid light fractions of both samples. Possible explanations for the differences in the size of recovered particles may be; a) variations in the mineral mode of occurrence of the gold and/or the morphology of the gold, b) variations in the efficiency of the processing technique used by the different laboratories, or c) contamination may have occurred during processing.

The weight of heavy minerals recovered by Laboratory 2 and 3 is the same, which may suggest that the original samples had the same proportion of the major heavy mineral components. The difference in the amount and size distibution of the gold recovered indicates that

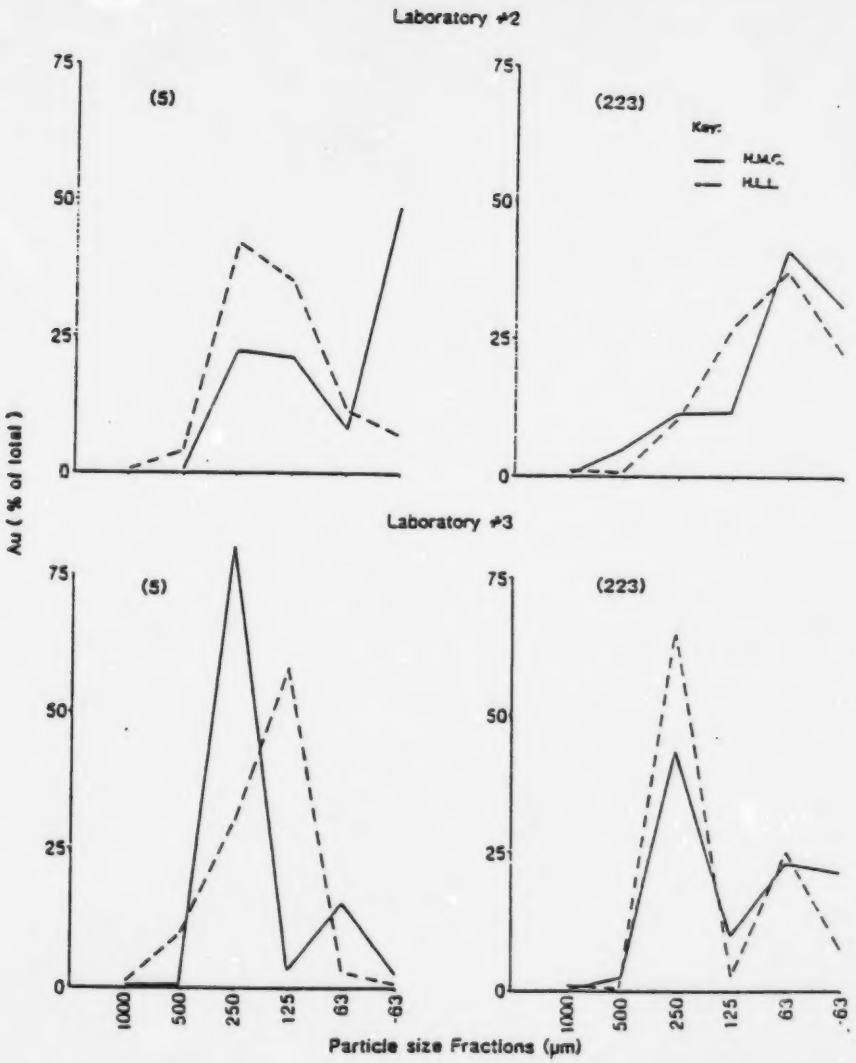


Figure 4.7 The percentage of the total gold in the various size fractions of heavy mineral concentrates of samples #5 and #223 processed by Laboratories 2 and 3.

Table 4.4. Comparison of gold contents of various fractions of the heavy mineral concentrating procedure on two samples prepared by two laboratories (values based on 5 kg of minus 2 mm material).

	Sample #5		Sample #223	
	Laboratory		Laboratory	
	2	3	2	3
Au (ppb)	2,175	69,135	19,945	29,177
HMC wt. (g)	3.06	3.03	5.2	5.1
Au (ng)	6,655	209,479	103,714	149,679
% of total Au in HMC	48	2	31	22
Au (ppb)	19	42	667	1,068
LTS wt. (g)	28.5	38.7	23.2	23.2
Au (ng)	540	1,625	15,465	24,751
Au LTs / Au LTS + HMC %	8	0.8	15	16.5
-63um fraction of HMC Au (ppb)	35,000	99,000	1,000,000	490,000
-63um fraction of HMC wt. (g)	.1	.5	.03	.07
-63um fraction of HMC Au. (ppb)	3,200	4,433	31,957	32,189
-500 to +250um fraction of HMC Au (ppb)	1,300	152,000	5,460	24,000
-500 to +250um fraction of HMC wt. (g)	1.1	1.1	2.2	2.66
-500 to +250um fraction of HMC Au (ng)	1,477	167,164	11,870	63,863
% of total Au in HMC	22	80	12	43
Total Au (ng)*	82,200	583,315	1,232,817	1,404,440

* The total gold in the original sample is calculated based on analyses of all fractions returned by the laboratory (Appendix C).

the gold in the samples is acting differently from the rest of the main heavy mineral components during the concentrating process.

In conclusion, the different amounts of gold recovered by the two laboratories is probably due to differences in the concentrating procedures adopted by each laboratory.

4:2:8 - Evaluation of Results Obtained by an Alternative Concentrating Procedure (Wet Sieving Process)

Because three different laboratories using similar procedures, produced widely differing results, an alternative concentrating process was examined. This technique, a wet sieving method (Section 3:2:4:2) has the advantage that little or no material is lost during processing. This allows for the determination of the true gold content of the original sample based on analysis of the various separatory fractions.

To further stress the problems with evaluating data based only on the concentration of gold the following example can be cited. The concentrations of gold in the heavy mineral concentrate fractions of samples #5 and #133 are 8651 and 7346 ppb, respectively (Table 4.5). These concentrations would be considered to be of equivalent exploration significance. But, because the heavy mineral concentrate from sample #133 is more than twice as heavy as that from sample #5, 20 g and 8.5 g respectively, the total amount of gold in the concentrate from sample #133 is commensurately higher in sample #5, and is therefore presumably of greater economic significance. To eliminate the effect of the dilution of the gold by the heavy minerals all further discussion of results will be restricted to the absolute

Table 4.5. Gold content in various fractions of heavy mineral concentrating procedure involving wet sieving(values based on 5 kg of minus 2 mm material)

		Owl Creek		Hemlo	
		#5	#306	#84	#133
Au in HMC	(ppb)	8,651	52,451	1574	7,346
	Wt.(g)	8.4	45.3	4.4	20.1
	Wt.(ng)	72,666	2,376,042	6,847	147,645
	% of total Au	31.0	30.4	1.4	11.0
Au in Intermediate HMC	(ppb)	44	3,810	85	547
	Wt.(g)	23.7	120	54.5	176.5
	Wt.(ng)	1,043	459,065	4,628	96,514
	% of total Au	0.5	5.9	1.0	7.2
Au in Light Mineral Fraction	(ppb)	20	1,015	58	202
	Wt.(g)	1,989	1,964	4,086	3,740
	Wt.(ng)	39,780	1,991,659	236,650	756,775
	% of total Au	16.5	26.0	47.0	56.3
Au in Suspension	Au(ppb)	42	1,043	300	322
	Wt.(g)	2,979	2,871	855	1,062
	Wt.(ng)	122,699	2,995,036	256,756	342,589
	% of total Au	52.0	37.7	50.6	25.5
Total Au in the sample (ng)		236,188	7,821,802	504,881	1,343,523

amount of gold present in the various fractions unless specifically stated to be otherwise.

4:2:8:1 - Partitioning of Gold

The amount of gold collected in the heavy mineral concentrates obtained from the four samples ranges from 1.4 to 36.2 percent of the total gold while in the intermediate mineral concentrates (S.G.>2.9<3.3) the amount of gold ranges from 0.5 to 7.2 percent of the total gold. Sample #5 shows an insignificant amount of gold in the intermediate fraction, but samples #306, #84 and #133 show significant amounts relative to the amount of gold in the heavy mineral concentrates. In sample #84 and #133, the intermediate fraction shows a comparable amount of gold to that in the heavy mineral concentrates. Therefore, these results suggests that tetrabromoethane should be used in the heavy mineral separation procedure to prevent the loss of significant amounts of gold. Because the density of tetrabromoethane, the results indicate that gold may be associated with low density minerals (for example, quartz).

It must also be noted that the material remaining in suspension contains a large amount of the total gold. In the case of sample #5, 52 % of the total gold in the original sample remains in the suspended material.

In conclusion, the proportion of gold collected in the heavy mineral concentrate is both low and variable and therefore raises questions as to the reliability of this heavy mineral concentrating procedure. Furthermore, although some of the gold that is normally discarded in the liquid lights can be retained by using

tetrabromoethane at the concentrating stage the situation is not improved. Finally, the material in suspension may contain a major proportion of the total gold and therefore should be retained at the sampling and processing stages to provide reliable data.

4:2:8:2 - Size Analyses

The distribution of the gold in the different size fractions of the various separatory fractions is variable (Figure 4.8). In the case of sample #5, the majority of the gold is in the minus 500 plus 125 µm fraction of the heavy mineral concentrate (S.G.>3.3), in the minus 125 plus 63 µm fraction of the intermediate heavy mineral concentrate (S.G.>2.9<3.3) and in the minus 1000 plus 250 µm fraction of the light material. The variable distribution of the gold between different fractions is also apparent in the other three samples. The different distributions patterns may be accounted for by the different mineralogical forms and shapes of the gold.

4:2:9 - Comparison of the Gold Recovery Using The Two Different Techniques

In order to place on a firmer basis the characteristics of different processes, data on four samples processed by Laboratories 2 and 4 are presented in Tables 4.6 and 4.7.

Up to a three-fold difference exist in the concentration of gold in the heavy mineral concentrates but up to a five-fold difference exist in the weight of gold (Table 4.6). A comparison of the total gold shows reasonable agreement for all samples.

A more detailed examination of the gold distribution within the

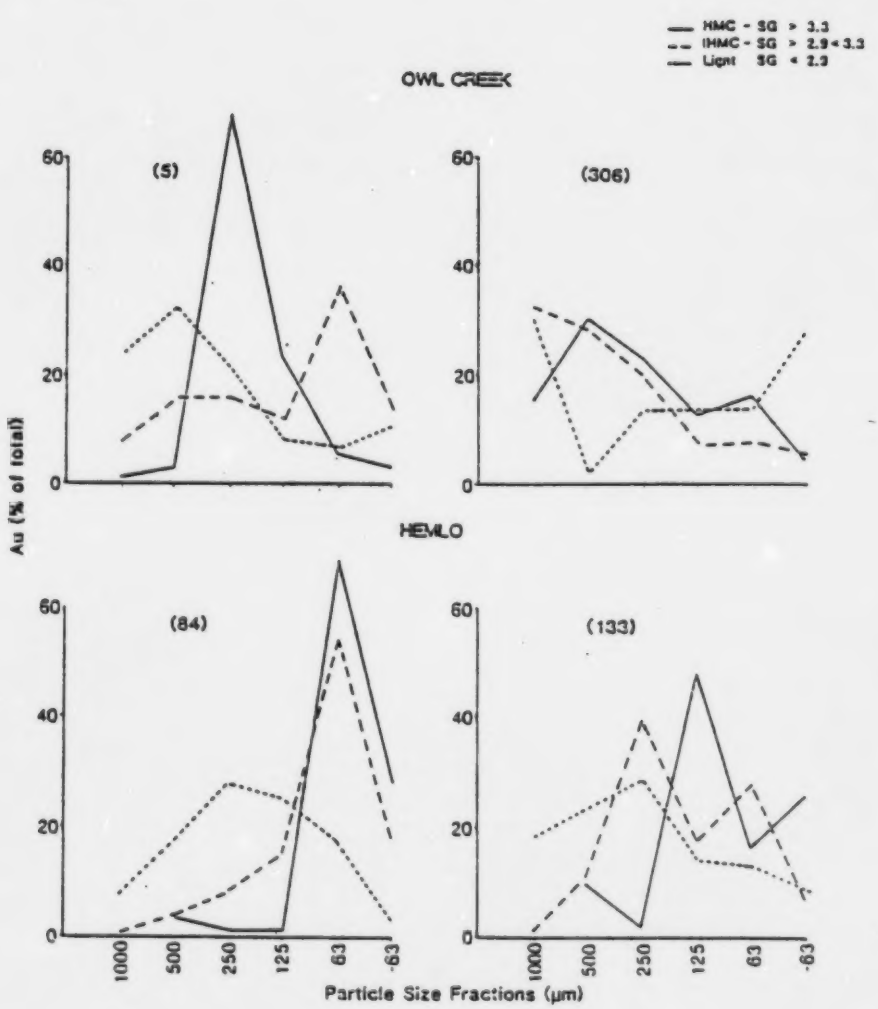


Figure 4.8 The distribution of the gold in the various size fractions of the various separatory fractions of samples processed by Laboratory 4.

Table 4.6. Comparison of gold recovered in heavy mineral concentrates prepared by Laboratory 2 and 4 (values based on 5 kg of minus 2 mm material).

	Lab	#5	#306	#84	#133
Au in HMC (ppb)	2 T	5,570	137,060	2,900	6,524
	4 W	8,651	52,451	1,574	7,346
Wt. of the HMC (grams)	2 T	2.90	11.20	6.74	16.30
	4 W	8.40	45.30	4.35	20.10
Wt. (ng)	2 T	16,153	1,535,072	19,574	106,341
	4 W	72,666	2,376,042	6,847	147,645
Total Au (ng)	2 T	311,000	11,335,581	449,935	1,332,330
	4 W	236,188	7,821,802	504,881	1,343,523
Au in HMC % of total Au	2 T	4.0	13.2	4.4	8.0
	4 W	31.0	30.4	1.4	11.0
Conc'n of Au in original sample (ppb)*	2	2.4	300	3.9	21.3
	4	14.5	475	1.4	29.5

T - Tabling process
W - Wet sieving process
* - the concentration of gold in the original sample is based on the premise that all the gold has been extracted into the HMC

size fractions of the heavy mineral concentrate (Table 4.7), shows that Laboratory 4 generally collects more gold in the plus 250 µm fraction. (This is in agreement with the observations noted in section 4:2:6:2.) On the other hand, Laboratory 2 collects at least an equal amount of gold in the minus 63 µm size fraction of the concentrates with up to seven times more gold in the case of sample #306. Expressed as a percent of the total gold, Laboratory 4 generally collects a greater percent in the coarser fractions while Laboratory 2 collects a greater percent in the finer fractions (Figure 4.9). In all cases, Laboratory 4 produced a greater concentrate weight from the same initial sample weight which may account for the more efficient collection of coarse-grained gold particles.

4:3 - Silt and Clay Fraction

4:3:1 - Dispersion of gold

As the majority of the gold is present in the minus 125 µm fraction of the tills, it may be possible to detect mineralization by directly analyzing the minus 63 µm fraction of tills. The presence of anomalous gold contents in the silt and clay fraction of till at the Hemlo deposit, extending over 500 m down-ice from mineralization, indicates the possibility of identifying Hemlo style mineralization on the basis of the direct analysis of the minus 63 µm fraction (Figure 4.10). Anomalous gold contents are present in tills from all traverses sampled over mineralization at Hemlo. The distribution of gold in the minus 63 µm fraction of tills is presented in Figures E.1 to 7, Appendix E.

Table 4.7. Comparison of the gold distribution within the concentrates processed by Laboratory 2 and 4 (values based on 5 kg of minus 2 mm material).

			Gold Content (ng)			
		Lab	#5	#306	#84	#133
	+1000	2	15	7,933	----	----
		4	345	356,823	----	----
F	+500	2	217	41,850	----	14,575
R		4	1,961	700,667	180	13,929
A						
S C	+250	2	1,723	132,800	4	19,743
I T		4	48,588	540,833	48	2,291
Z I						
E O	+125	2	1,721	244,200	408	23,024
N		4	16,250	296,563	52	71,500
S						
(um)	+63	2	6,756	375,000	7,661	18,000
		4	3,451	382,292	4,667	23,282
	-63	2	1,692	696,667	11,500	31,000
		4	2,101	98,958	1,900	36,643

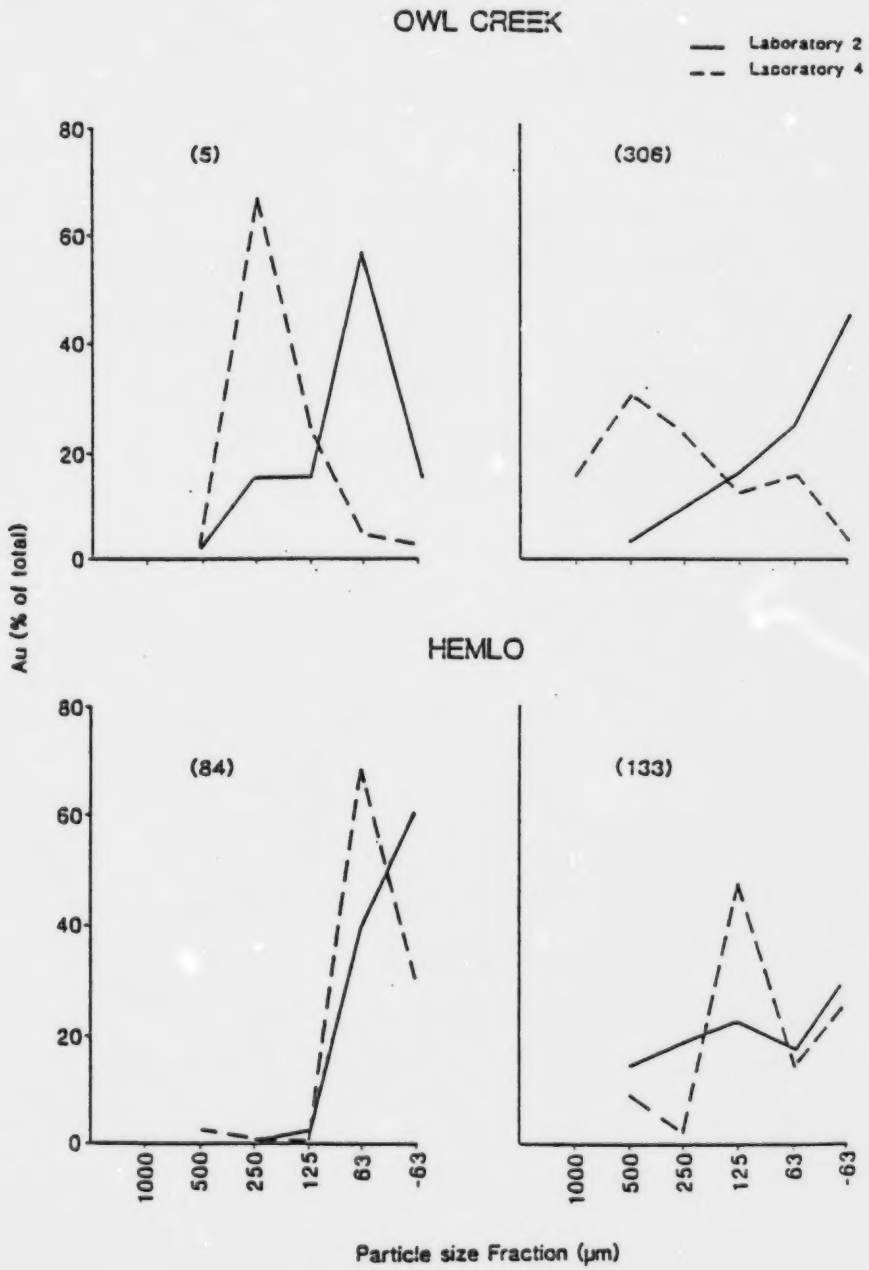


Figure 4.9 A comparison of the distribution of the gold in heavy mineral concentrates of specific samples processed by Laboratories 2 and 4.

The minus 63 µm fraction of all till samples taken immediately down-ice from the McBean mineralization contained less than 10 ppb gold, which are considered to be background values. A sample taken up-ice of the mineralization, thought initially to be a background sample, contained 125 ppb in the minus 63 µm fraction. This suggests that the gold content of this anomalous sample could be derived from another mineralized source other than the McBean mineralization. The gold in the minus 63 µm fraction may be mechanical and/or chemically transported gold. In summary, analysis of the minus 63 µm fraction of this till may prove successful in identifying mineralization.

A possible explanation as to why gold is present in the minus 63 µm fraction of heavy mineral concentrates obtained from the McBean samples but not present in the bulk minus 63 µm fraction of these samples is that the gold particle size is close to 63 µm. Therefore, the 8 grams of minus 63 µm of the bulk material taken for analysis is not representative for the gold particle size and concentrations present in the sediments.

As background gold contents are present in the the minus 63 µm fraction of tills immediately down-ice from the McBean mineralization the minus 63 µm fraction of these tills was not processed by the cyclosizer.

4:3:2 - Grain Size Distribution

The relative proportions of hydraulically equivalent fractions of the silt and clay material (minus 63 µm) show variations amongst deposits (Figure 4.11). The Owl Creek samples show a predominance of the lowest hydraulically equivalent fraction while the Hemlo samples

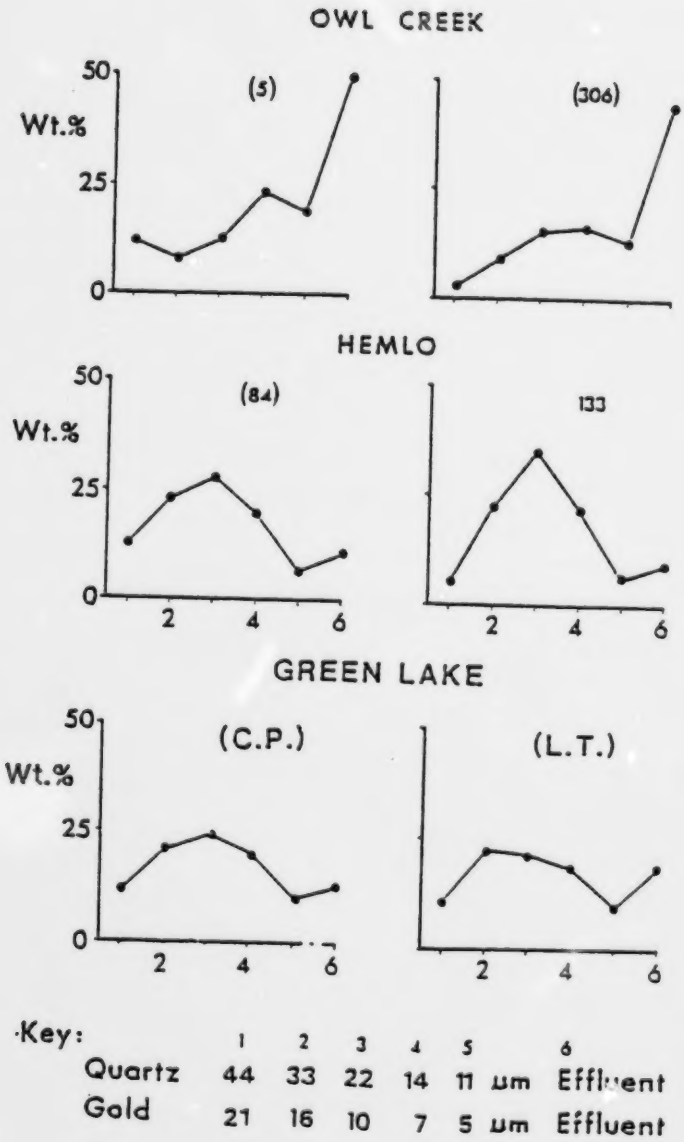


Figure 4.11 The hydraulically equivalent particle size distribution in the minus 63 um fraction of tills.

and to a lesser degree the Green Lake samples, show a predominance of the intermediate hydraulically equivalent fractions.

4:3:3 - Size Analyses

The proportion of total gold in fractions of different hydraulic equivalence is similar in tills from the same deposit but varies between deposits (Figure 4.12).

A bimodal distribution of the gold is present in sample #5, from Owl Creek, with the greatest amounts of gold in the fractions of highest and lowest hydraulic equivalence. For sample #306 the majority of the gold is only in the fraction of highest hydraulic equivalence.

In the Hemlo samples the gold is evenly distributed throughout the minus 63 µm fraction of the tills.

In the case of Green Lake, a bimodal distribution of the gold is present with the largest amounts of gold in fractions of highest and lowest hydraulic equivalence.

Variations in the distribution of gold in the silt and clay fraction of the tills may indicate; variations in the shape and size of gold grains, differences in the mineralogical mode of occurrence of the gold and/or differences in the provenance of the gold. As a consequence of these differences in the sizes of the gold grains the size of a representative till sample will vary in accordance with the deposit sampled.

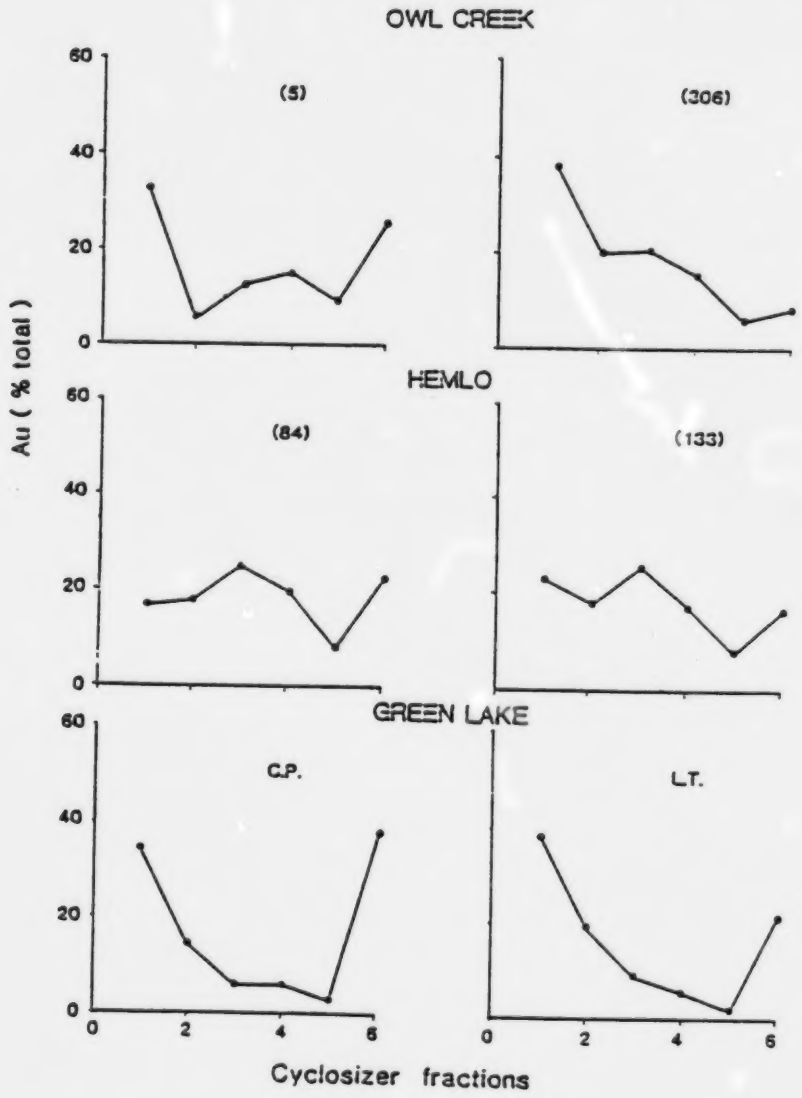


Figure 4.12 The distribution of gold within the minus 63 um fraction of tills.

4:3:4 - Comparison of Silt and Clay Fraction to Heavy Mineral Concentrates

Sonic core samples taken down-ice from the Owl Creek deposit and heavy mineral concentrate data were made available to the project by Kidd Creek Mines Ltd.. The minus 63 µm fraction of each sample was analyzed and the results compared to the heavy mineral concentrate data (Figure 4.13). The minus 63 µm gold data and the heavy mineral concentrate data show similar patterns. Therefore, the minus 63 µm fraction should be an important component of any gold geochemical exploration programme. Further, analysis of the minus 63 µm fraction can improve the representativeness of the sample and the cost of processing is dramatically less than that involved in the production of heavy mineral concentrates.

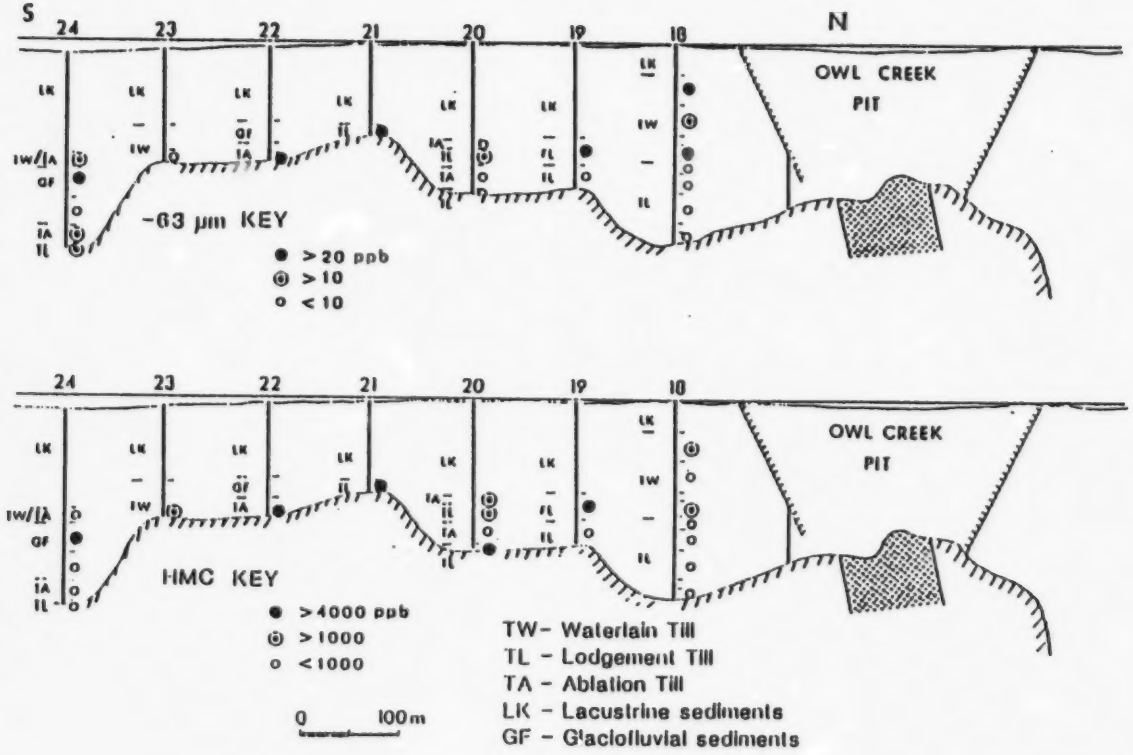


Figure 4.13 A comparison of the gold distribution in the heavy mineral concentrate and the minus 63 um fraction of till from Owl Creek.

Chapter 5

Summary and Conclusions

5:1 - Nature Of The Investigation

Previous studies have shown that the finer size fractions of till contain anomalous gold contents. However, this fraction of the tills has been generally ignored in geochemical exploration for gold. The most widely used till sampling method in areas of deep overburden is the reverse circulation drill, a technique which fails to collect a significant proportion of material in the finer size fractions of tills. Furthermore, with any collection system, problems still exist when a representative field sample is collected and then processed by a heavy mineral concentrating techniques. These processes lose the majority of the fine-grain sized material in the form of effluent.The loss of this fine-grained material at the sampling and processing stage also suggests a loss of fine-grained gold. The purpose of the present study was to examine the distribution of gold in till from areas of known mineralization, to evaluate the adequacy of the currently used geochemical exploration techniques and to try to improve the reliability of the geochemical techniques used in gold exploration.

5:2 - Study Areas

In view of the diverse character of gold in gold deposits the

Owl Creek, Hemlo, and McBean Mine deposits and the Green Lake occurrence were selected for study as they provide a range of mineralogical forms of the gold coupled with variations in the gold particle size. This diversity in character of the gold was necessary to provide material representative of different types of gold deposits.

5:3 - Approach To The Problem

5:3:1 - Sampling

At the Owl Creek and McBean deposits and the Green Lake showing, bulk till samples were collected. These tills, consisting of a large component of locally derived material, were collected from locations over or just down-ice from mineralization. The bulk till samples collected at Hemlo were selected on the basis of previously obtained gold analysis.

5:3:2 - Sample Processing

A particle size analysis of the bulk till samples and the heavy mineral concentrates obtained from these tills was completed by wet sieving. The minus 63 µm material was separated into hydraulically equivalent fractions using a Warman Cyclosizer.

The distribution of the gold was determined by analyzing all particle size fractions of the heavy mineral concentrates and all hydraulically equivalent fractions of the minus 63 µm material of the tills.

5:3:3 - Analysis

All samples were analyzed for gold using Instrumental Neutron Activation Analysis (INAA). The following fractions of each till were analyzed: a) a bulk 63 µm fraction, b) hydraulically equivalent fractions of the minus 63 µm material, and c) particle size fractions of the non-magnetic heavy mineral concentrate, the magnetic heavy mineral concentrate, the heavy liquid light material, and the table light material.

The main advantage of the INAA method is that it is non-destructive and therefore the samples can be visually examined following irradiation and may be re-analyzed.

5:4 - Summary of the Results

5.4.1 - Particle Size Composition of the Bulk Till Samples

The minus 63 µm material constitutes 20 - 50 % of the minus 2 mm fraction of the tills associated with gold mineralization.

5.4.2 - Heavy Mineral Concentrates

The non-magnetic heavy mineral concentrates of tills are dominantly composed of the minus 500 to plus 63 µm material and include only an insignificant proportion of silt and clay sized material. This feature demonstrates the non-representivity of the heavy mineral concentrate in terms of the bulk sample, a feature attributable to the inability of gravity techniques to efficiently collect fine-grained material.

Although the heavy mineral concentrate shows a pronounced enhancement of gold relative to that in the bulk sample, analysis of the heavy mineral concentrate and various other separatory fractions revealed that generally less than 15 % of the gold present in the original sample has been concentrated into the non-magnetic heavy mineral fraction. This coupled with the fact that the percentage of the gold concentrated varies amongst samples, from 1 - 15 %, reduces the reliability that can be attached to the interpretation of gold data based on analysis of heavy mineral concentrates.

Examination of the partitioning of the gold in the non-magnetic heavy mineral concentrates shows that greater than 90 % of the gold is present in the minus 500 µm fraction of the tills. The majority of this gold is in the minus 125 µm fraction. Gravity concentrating techniques have been shown to be inefficient at concentrating gold particles in this size range. This observation draws attention to the possible non-detection of fine-grained gold deposits due to the small proportion of fine-grained gold recovered by the heavy mineral concentrating procedure.

As stated previously, the concentration factor is a ratio of the weight of the original sample to that of the heavy mineral concentrate. The weight of the heavy mineral concentrate varies in accordance with the host rock lithology and the mineralogy of the deposit. This results in widely varying gold concentrations in the heavy mineral concentrate with the possibility that a sample with a high heavy mineral concentrate weight but only an intermediate gold concentration may be overlooked. The solution is to express the gold

content as contained gold (weight of gold per standard weight of sample).

5.4.3 - Inter-laboratory Comparison

Results show that for a particular sample varying amounts of gold are being concentrated by different laboratories using a similar tabling and heavy liquid technique. The results indicate that different laboratories recover heavy mineral concentrates that show up to 54 fold variations in the concentration of the gold, 6 fold variations in the weight of the heavy mineral concentrate and up to 39 fold variations in the total contained gold. In addition, the size distribution of the gold in the heavy mineral concentrate varies dramatically with laboratories alternately showing the majority of gold in the finer size ranges or the intermediate size ranges. A possible explanation for the differences may be due to the inherent characteristics of the various techniques used by individual laboratories. Nevertheless, they indicate that considerable caution is necessary when comparing data from different laboratories.

In a comparison of the efficiency of the tabling and the wet sieving methods, the latter collects more gold in the coarser size fractions. The reasons may be that the wet sieving process loses less gold and that the heavy liquid separation is more efficient for the restricted particle size ranges obtained by the wet sieving method. A distinct advantage of the wet sieving method is that all material can be recovered and all fractions analyzed to determine the true gold content of the original sample.

5:4:4 - Silt and Clay Fraction

As the minus 63 µm material constitutes 20 - 50 % of the minus 2 mm fraction of tills it can be considered as a possible sample fraction for the detection of fine-grained gold deposits as well as coarse-grained gold deposits providing they have a fine-grain sized component.

Analysis of the minus 63 µm fraction of tills provide a number of attractive features:

a) anomalous gold contents have been shown to be present in the minus 63 µm fraction of tills associated with gold deposits,

b) analysis of the minus 63 µm fraction improves sample representativeness,

c) the cost of processing the minus 63 µm fraction is relatively small,

d) in those cases when gold data obtained from analysis of the minus 63 µm fraction is compared to that obtained from heavy mineral concentrates similar dispersion patterns are present,

e) the problems inherent in the heavy mineral concentrating procedures do not exist when considering gold data based on analysis of the minus 63 µm fraction,

and f) perhaps most importantly, the chances of detecting fine-grained gold deposits devoid of any coarse-grained gold are vastly improved compared to the chances using the heavy mineral concentrate procedure.

5:4:5 - Summary

Notwithstanding the proven success of heavy mineral concentrate

analysis in gold exploration the results of the current investigation indicate some inherent weaknesses in the procedure. Potential limitations include:

a) the non-representativeness of the heavy mineral concentrate in terms of the bulk composition of till,

b) a variable relationship of the heavy mineral concentrate gold content to the total gold content of the original sample,

c) the majority of gold in till being in the minus 125 µm fraction is not recovered quantitatively by the separatory process and thus there is an inherent risk of not recognizing fine-grained gold deposits,

d) the varying degrees of concentration between the original sample weight and the heavy mineral concentrate weight can be attributed to the differing amounts of heavy minerals which could result in overlooking significant samples.

However, the examination of the morphology and the number of gold grains in the heavy mineral concentrate provide useful information in terms the proximity to mineralization.

It is not known at this time whether the gold in the minus 63 µm fraction is mechanically transported fine-grained gold grains, gold comminuted during transport or hydromorphically transported gold deposited from groundwater. An understanding of the origin of the gold in the fine fraction is of importance in order to reliably interpret the gold contents of the fine sized fractions.

Based on the results obtained on the tills selected from the four deposits, direct analysis of the minus 63 µm fraction appears to be a suitable exploration approach and a useful supplement to the

conventional procedure of heavy mineral concentrate analysis.

In conclusion, it is apparent that the overall effectiveness of geochemical exploration techniques used in searching for the variety of gold deposits that are known to exist can be significantly improved with the adoption of a number of refinements.

5:5 - Exploration Methodology

5:5:1 - Heavy Mineral Concentrates

The gold content of the heavy mineral concentrates should be expressed in terms of the total contained gold rather than as concentration to overcome the differential dilution of the gold due to varying amounts of heavy minerals.

5:5:2 - Silt and Clay Fraction

On the assumption that the small proportion of the silt and clay fraction of till collected by the reverse-circulation drill is representative of the silt and clay fraction of the till as a whole, the silt and clay fraction should be analyzed directly for gold. The fine grained material is more homogeneous than the coarser fractions and should improve the chances of detecting a wide variety of gold deposits.

5:6 - Recommendations For Future Work

Improvements in the methods used in geochemical exploration for gold may be attained at two stages of a programme.

5:6:1 - Sample Collection

First, a representative field sample must be collected. In areas of shallow overburden, a representative sample of till can be obtained by trenching. Meanwhile, in areas where the till is deeply buried a representative sample can be collected by using the rota-sonic drill or a portable drill, for example in the latter case; Pionjar, if the gold present in the till is fine grained gold and a small sample is sufficiently representative. If reverse-circulation drilling continues to be used instead of the rota-sonic drilling then the reverse-circulation drill must be adapted to allow collection of a representative sample. One possible method is the collection and the analyses of the effluent from the collection bucket. Preliminary results indicate that the effluent can be collected using a flocculating agent. Since the reverse-circulation drill can be converted to diamond bit coring, the other alternative is to adopt the triple tubing procedure. It is essential that the drill bit designed for this procedure is used to ensure that a high percentage of the core is recovered.

5:6:2 - Sample Processing

Results from the present study indicate that the heavy mineral concentrating procedure only collects a small fraction of the gold with a major proportion of the gold being lost in the effluent. Hence one approach would be to flocculate the material suspended in the table effluent and analyze it separately. This information in itself may be useful in exploration. The second approach could be to physically separate the minus 63 μm fraction and analyze it directly

or the gold in the minus 63 μm fraction could be concentrated by froth flotation.

One possible method of improving the efficiency of the tabling process would be to use a more restricted particle size range for the table feed to improve the recovery of the finer sized gold particles. Significant improvements in the percent gold recovery have been noted during testing of other gravity concentrating techniques (Poling, pers. comm., 1985).

Possible improvements may also be achieved at the heavy liquid stage of the heavy mineral concentrating procedure. Firstly, tetrabromoethane could be used to recover a greater percentage of the gold, specifically that gold that is not liberated but is present as inclusions in minerals of lower specific gravity. Secondly, the volume of the heavy liquid should be increased to give a greater volume of liquid to volume of heavy minerals ratio to improve the separation.

Finally, an examination of the element association present in gold grains present in the till may prove helpful in determining the provenance of the gold.

It is recognized that all these additions to the current procedures will add to the total cost of exploration but if it can be shown they provide important technical advantages, thereby increasing exploration reliability, the additional costs may be fully justified.

APPENDIX A

SAMPLE PREPARATION

A.1 DETERMINATION OF PARTICLE SIZE DISTRIBUTION

A.1.1 BULK SAMPLE

Determination of the particle size distribution of the bulk sample is as follows:

1) One kilogram of each till was used for size analysis.

2) The minus 2 mm fraction of the till was separated by wet sieving.

3) The minus 2 mm material was separated in six fractions (minus 2000 - plus 1000 µm; minus 1000 - plus 500 µm; minus 500 - plus 250 µm; minus 250 - plus 125; minus 125 - plus 63 µm and the minus 63 µm) by wet sieving.

4) Each size fraction was dried then weighed.

A.1.2 HEAVY MINERAL CONCENTRATES

Determination of the particle size distribution of the heavy mineral concentrates is as follows:

1) Each heavy mineral concentrate was separated in six fractions (minus 2000 - plus 1000 µm; minus 1000 - plus 500 µm; minus 500 - plus 250 µm; minus 250 - plus 125 µm; minus 125 - plus 63 µm and the minus 63 µm) by wet sieving.

2) Each size fraction was dried, weighed and then sent for analysis to determine the gold distribution.

A.1.3 MINUS 63 µm FRACTION

The distribution of particles was determined by a Warman Cyclosizer. The cyclosizer separates the particles into hydraulically equivalent fractions. The preparation is as follows:

1) Approximately 500 g of the minus 63 µm material was processed.

2) This fraction was mixed with water using a flotation cell. The mixing action dispersed the finer material so that each particle would act independently during processing by the cyclosizer.

3) Approximately 75 g of the material is processed at a time.

4) After each run the sample fractions are removed from the collection cups at the top of each cyclone.

5) The hydraulically equivalent fractions are then dried, weighed, and then sent for analysis.

APPENDIX B

B.1 SAMPLE KEY

All samples are listed by sample number and identified by site location and sample type.

Legend

Areas

G.S. - Golden Sceptre
T.C. - Teck Corona
W. - Williams
K. - Kearns
O.C. - Owl Creek
M.M. - McBean Mine
G.L. - Green Lake

Sample Description

#1 - Sample number
HMC - heavy mineral concentrate
MAG - magnetic HMC
LLT - Liquid light fraction
TLT - Table light fraction
cycl # - cyclone #
Ae - Eluviated horizon
B - Fe or clay rich horizon
f-iron rich
g-gleysol
t-clay rich
Till - C horizon
a-ablation till
fl-flow till
l-lodgment till
w-waterlain till
ox-oxidized till
unox-unoxidized till
S - Saprolite

SAMPLE KEY

Sample Number	Sample Description	Media
50-0001	K.	T
50-0002	O.C.	Tw
3	O.C.	Ta
4	O.C.	Tf1
5	O.C.	T1
6	W- 17+50E,5+75S	Tunox
7	"	Tox
8	6+00S,	T
9	6+25S	T
9A	5+85S	Ta
10	"	T
11		S
12	T.C.-L12, 3+00N	T
13	"	Bg
14	3+25N	T
15	"	Bf
16	"	Ae
17	3+50N	Ae
18	"	Bf
19	"	T
20	3+75N	Ae
21	"	Bf
22	2+75N	T
23	2+50N	T
24	"	Bg
25	2+00N	Ae
26	"	Bf
27	"	T
28	1+50N	T
29	1+00N	Bf
30	"	T
31	0+00	Ae
32	"	Bf
33	T.C.,-L34, 4+32N	Ae
34	"	B
35	"	T
36	3+70N	Bf
37	3+50N	Ae
38	"	B
39	3+28N	Ae
40	"	Bf
41	3+00N	T
42	2+50N	T
43	1+50N	Ae

44		"	Bf
45		0+00	Org
46		4+90N	Ae
47		"	Bf
48		5+12N	Bf
49		5+35N	Bf
50		5+65N	Bg
51		5+90N	Ae
52		"	Bf
53		"	T
54		8+00N	T
55		"	B
56		8+75N	Ae
57		"	B
58		"	T
59	T.C.,	3+86N	B
60	(trench)	"	T
61		4+02N	T
62		"	B
63		4+39N	Ae
64		"	B
65		"	T
66		4+84N	Ae
67		"	B
68		"	T
69		5+95N	Ae
70		"	B
71		"	T
72		6+90N	B
73	T.C.-16W,	5+00S	Ae
74	(smear)	"	B
75		6+50S	Ae
76		"	B
77		7+10S	Ae
78		"	B
79		"	T
80		7+50S	Ae
81		"	B
82		8+00S	Ae
83		"	B
84		"	T
85		8+50S	Ae
86		"	B
87		"	T
88		9+50S	Ae
89		"	B
90		10+00S	Ae
91		"	B
92		"	T
93		10+50S	Ae
94		"	B
95		11+00S	B
96		12+00S	Ae
97		"	B

98	T.C.-	6+38N	Ae
99	(trench)	"	B
100	G.S.,16W,	5+00S	B
101	5+00S		Ae
102	"		B
103	4+00S		Ae
104	"		B
105	"		T
106	2+90S		Bg
107	2+00S		Ae
108	"		B
109	1+00S		Ae
110	"		B
111	"		T
112	G.S.,14W,	8+00S	B
113	5+00S		Ae
114	"		T
115	"		B
116	3+00S		T
117	2+10S		Ae
118	1+00S		Ae
119	"		B
120	"		T
121	0+50S		Ae
122	"		B
123	"		T
124	0+00		Ae
125	"		B
126	"		T
127	0+25N		Ae
128	"		B
129	"		T
130	"		S
131	0+50N		Ae
132	"		B
133	"		T
134	0+75N		Ae
135	"		B
136	"		T
137	1+00N		B
138	1+25N		B
139	2+10N		B
140	"		T
141	2+50N		Bg
142	"		T
143	3+00N		Bg
144	"		T
145	4+40N		Bg
146	5+50N		Ae
147	7+00N		Ae
148	"		B
149	G.S.	2W,16+00S	Ae
150	16+00S		T
151	"		B

152	10+00S	B
153	"	T
154	0+00	B
155	"	T
156	0+25N	B
157	"	T
158	0+50N	B
159	"	T
160	0+75N	Ae
161	"	Bs
162	1+00N	S
163	1+25N	Ae
164	"	B
165	"	T
166	5+00S	Tg
167	2+00S	B
168	1+00S	Ae
169	"	B
170	0+50S	B
171	2+00N	B
172	"	T
173	2+75N	B
174	4+00N	B
175	5+30N	Ae
176	"	B
177	7+75N	Ae
178	"	B
179	9+10N	Ae
180	"	B
181	10+60N	Ae
182	"	B
200	G.S.,20W,15+00S	Ae
201	15+00S	B
202	10+00S	Ae
203	5+00S	Ae
204	"	B
205	"	T
206	3+00S	Ae
207	"	B
208	2+00S	Ae
209	"	B
210	"	T
211	1+00S	Ae
212	"	B
213	0+50S	B
214	"	T
215	0+00	T
216	0+25N	T
217	0+50N	Ae
218	"	B
219	0+75N	T
220	1+00N	Ae
221	"	B
222	"	T

223	1+25N	B(T)
224	1+50N	Ae
225	"	B
226	1+75N	Ae
227	"	T
228	2+00N	T
229	2+50N	B
230	3+00N	B
231	"	T
232	3+50N	Ae
233	"	B
234	"	T
235	4+50N	Ae
236	"	B
237	6+00N	Bg
238	7+00N	Bt
239	10+00N	Ae
240	"	B
300	M.M.P.	T
301	"	T
302	"	T
303	"	T
304	"	T
305	"	T
306	O.C.P.	T
310	G.S.,12W, 5+00N	T
311	7+00N	T
312	9+00N	T
313	G.S.,14W, 4+40N	T
314	6+00N	Ae
315	"	B
316	"	T
317	7+20N	Ae
318	"	B
319	8+00N	B
320	"	T
321	9+00N	Ae
322	"	B
323	"	T
324	10+00N	T
325	G.S.,20W, 5+00N	T
326	5+75N	B
327	6+50N	B
328	7+50N	B
329	"	T
330	9+75N	B
331	"	T
332	4+30S	B
333	"	T
334	6+50S	B
335	"	T
336	T.C.,L34, 8+75N	T
337	8+75N	B
338	8+00N	Ae

339	"	B
340	"	T
341	3+50N	T
342	3+30N	T
343	"	B
344	1+50N	T

APPENDIX C

ANALYTICAL GOLD DATA

C.1 DATA LISTING

The data as determined by Instrumental Neutron Activation Analysis are given in Table C.1. The vial number, the sample description, and the gold concentration are listed by sample set number.

Table C.1 Gold analyses.

Sample Set #1

Vial Number	Sample Description	Weight (grams)	Gold (ppb)
1-1	#1 cyclone #'s	8.46	31
1A		8.60	3
1B		8.51	18
2		8.60	15
3		8.45	22
3A		8.58	18
3B		8.52	17
4		8.57	43
5		8.46	28
5A		8.54	36
5B		8.48	22
6	-180 +120	8.57	<4
6A	-120 +120	8.50	6
6B	-120 +120	8.49	<4
7	-120 +200	8.56	<4
8	-200 leftover	8.50	9
8A	"	8.53	12
1-8B	"	8.54	8
2-1	#1 cyclone #'s	8.50	345
1A		8.50	213
1B		8.49	278
2		8.51	108
3		8.49	61
3A		8.54	73
3B		8.58	52
4		8.55	62
5		8.50	49
5A		8.58	55
5B		8.50	54
6	-180 +120	8.56	8
6A	-120 +120	8.55	7
6B	-120 +120	8.49	16
7	-120 +200	8.59	8
8	-200 leftover	8.52	66
8A	"	8.52	77
2-8B	"	8.53	49

Sample Set #2

Vial Number	Sample Description	Weight (grams)	Gold (ppb)
2-1	Silica #1 cycl 1	6.5	<2
2	1	6.5	<2
3	1	6.6	<2
4	2	6.5	<2
5	3	6.5	5
6	4	6.5	5
7	4	6.5	5
8	#3 cycl 5	6.6	56
9	5	6.6	52
2-10	5	6.5	46
11	4	6.5	71
12	3	6.5	87
13	3	6.5	67
14	2	6.5	59
15	2	6.5	60
16	1	6.5	230
17	1	6.5	170
18	1	6.5	170
19	effluent	6.5	37
2-20	effluent	6.5	43
21	effluent	6.5	35
22	Silica #3 cycl 1	6.5	<2
23	1	6.5	<2
24	1	6.5	<2
25	2	6.5	3
26	3	6.5	3
27	4	6.5	<2
28	5	6.5	2

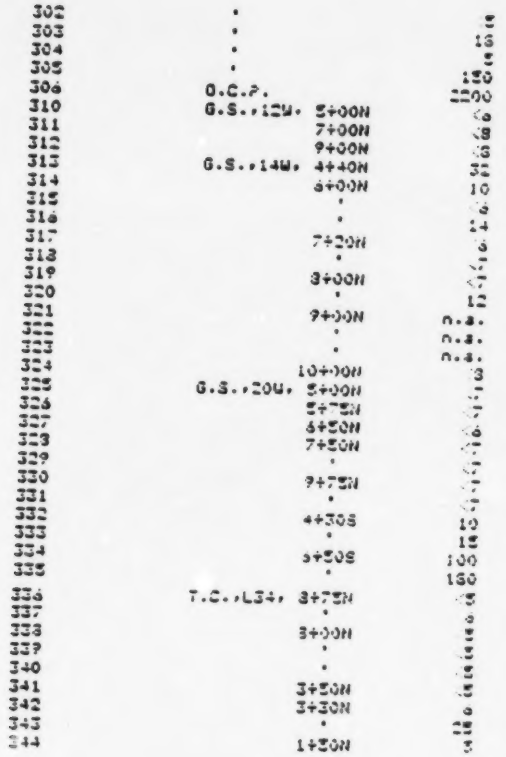
Sample Set #3

Approximately 6 grams of the minus 63 um material of each sample was analyzed.

Sample Number	Sample Description	Gold (ppb)
30-0001	K.	10
30-0002	O.C.	-
3	O.C.	-
4	O.C.	-
5	O.C.	64
6	W- 17+50E, 5+75S	6
7	"	20
8	6+00S,	63
9	6+25S	<6
9A	5+85S	67
10	"	15
11	"	5100
12	T.C.-L12, 3+00N	n.a.
13	"	5
14	3+25N	27
15	"	11
16	"	19
17	3+50N	<5
18	"	n.a.
19	"	41
20	3+75N	6
21	"	32
22	2+75N	13
23	2+50N	5
24	"	<5
25	2+00N	7
26	"	6
27	"	22
28	1+50N	17
29	1+00N	5
30	"	<5
31	0+00	<6
32	"	8
33	T.C.-L34, 4+30N	7
34	"	<6
35	"	27
36	3+70N	10
37	3+50N	6
38	"	<6
39	3+28N	9
40	"	n.a.
41	3+00N	14
42	2+50N	10
43	1+50N	5
44	"	<6
45	0+00	17
46	4+90N	5
47	"	21
48	5+10N	37
49	5+35N	6
50	5+65N	6
51	5+90N	11
52	"	<6
53	"	<4
54	8+00N	n.a.
55	"	n.a.
56	8+75N	n.a.
57	"	n.a.
58	"	n.a.
59	T.C. , 3+86N	140
60	(trench) "	44
61	4+02N	28
62	"	16
63	4+37N	5
64	"	<6
65	"	<7
66	4+84N	<6
67	"	<5
68	"	<4
69	5+95N	<4
70	"	5

71		·	<5
72		6+90N	<5
73	T.C.-16W,	5+00S	<5
74	(saear)	·	31
75		6+30S	44
76		·	27
77		7+10S	37
78		·	49
79		·	25
80		7+50S	107
81		·	241
82		8+00S	66
83		·	116
84		·	885
85		8+50S	62
86		·	145
87		·	72
88		9+50S	43
89		·	15
90		10+00S	19
91		·	12
92		·	58
93		10+50S	42
94		·	15
95		11+00S	9
96		12+00S	n.a.
97		·	<5
98	T.C.-	6+25N	<5
99	(trench)	·	5
100	G.S.,16W,	5+00S	24
101		·	41
102		·	13
103		4+00S	7
104		·	6
105		·	<5
106		2+90S	17
107		2+00S	41
108		·	31
109		1+00S	n.a.
110		·	<5
111		·	40
112	G.S.,14W,	8+00S	<5
113		5+00S	12
114		·	29
115		·	16
116		3+00S	14
117		2+10S	15
118		1+00S	62
119		·	46
120		·	31
121		0+50S	10
122		·	8
123		·	59
124		0+00	39
125		·	39
126		·	76
127		0+25N	9
128		·	47
129		·	134
130		·	2690
131		0+50N	19
132		·	93
133		·	138
134		0+75N	16
135		·	19
136		·	118
137		1+00N	105
138		1+25N	124
139		2+10N	32
140		·	81
141		2+50N	142
142		·	91
143		3+00N	67
144		·	41
145		4+40N	229
146		5+50N	<5
147		7+00N	7
148		·	7

149	G.S.,12U,	16+00S	9
150		"	6
151		"	5
152		10+00S	5
153		"	38(DD)
154		0+00	55(DD)
155		"	47
156		0+25N	70(DD)
157		"	n.s.
158		0+50N	171
159		"	147
160		0+75N	16,300
161		"	1,760
162		1+00N	162
163		1+25N	288
164		"	390
165		"	402
166		3+00S	18
167		2+00S	96
168		1+00S	250
169		"	98
170		0+50S	219
171		2+00N	96
172		"	248
173		2+75N	533
174		4+00N	49
175		5+30N	n.s.
176		"	n.s.
177		7+75N	5
178		"	n.s.
179		9+10N	5
180		"	6
181		10+60N	6
182		"	6
200	G.S.,20U,	15+00S	7
201		"	9
202		10+00S	4
203		5+00S	10
204		"	n.s.
205		"	7
206		3+00S	8
207		"	5
208		2+00S	45
209		"	12
210		"	95
211		1+00S	61
212		"	41
213		0+50S	422
214		"	945
215		0+00	27
216		0+25N	36
217		0+50N	32
218		"	23
219		0+75N	n.s.
220		1+00N	14
221		"	28
222		"	29
223		1+25N	287
224		1+50N	69
225		"	164
226		1+75N	26
227		"	33
228		2+00N	154
229		2+50N	142
230		3+00N	21
231		"	n.s.
232		3+50N	259
233		"	111
234		"	37
235		4+50N	43
236		"	75
237		6+00N	48
238		7+00N	48
239		10+00N	9
240		"	17
300	M.M.P.		7
301		"	8


G.C.P.
G.S.,12W, 5+00N
7+00N
9+00N
G.S.,14W, 4+40N
6+00N
7+20N
8+00N
9+00N
10+00N
G.S.,20W, 5+00N
5+75N
6+50N
7+50N
9+75N
4+30S
5+50S
T.C.,L34, 8+75N
8+00N
3+50N
3+30N
1+30N

Sample Set #4

Vial Number	Sample Description		Weight (grams)	Gold (ppb)
4-1	Cominco #5	HMC	12.4	150
2	Lab	MAG	1.3	<14
3		LLT	10.1	5
4	-10 rejects	A	10.3	15
5		B	10.4	9
6		C	10.3	6
7	-63 um	A	6.8	46
8		B	6.8	44
9		C	6.8	44
4-10	#1	HMC	4.0	1500
11		MAG	1.3	<16
12		LLT	10.3	24
13	-10 rejects	A	10.4	9
14		B	10.4	4
15		C	10.4	5
16	-63 um	A	6.8	8
17		B	6.8	4
4-18		C	6.8	3

Sample Set #5

Vial Number	Sample Description		Weight (grams)	Gold (ppb)
5-1	McBean #300	-63 um	6.0	7
2	#301	"	6.0	8
3	#302	"	6.0	5
4	#303	"	6.0	18
5	#304	"	6.0	5
6	#305	"	6.0	150
7	#306	"	6.0	2200
8	rock sample		6.0	20
9	"		6.0	12
5-10	"		9.0	6
11	"		9.0	9

Sample Set #7

Vial Number	Sample Description		Weight (grams)	Gold (ppb)
7-1	20W 5N	C	5.5	<7
2	14W 6N	Ae	5.5	10
3	12W 7N	C	5.5	<8
4	16W 8S	C	5.5	120
5	16W 8S	C	5.5	130
6	14W 1N	C	5.5	360
7	20W 5N	C	5.5	<6
8	14W 0+50N	C	5.5	430
9	14W 0+50N	C	5.5	260
7-10	20W 4+30S	C	5.5	15
11	Control		5.5	280
12	12W 2+50N	C	5.5	630
13	20W 5+75N	B	5.5	<7
14	14W 10N	C	5.5	<8
15	14W 6N	C	5.5	14
16	20W 6+50N	B	5.5	100
17	14W 4+40N	C	5.5	32
18	20W 7+50N	C	5.5	<7
19	20W 9+75N	C	5.5	<7
7-20	14W 7+20N	B	5.5	<7
21	20W 7+50N	B	5.5	<7
22	Control		5.5	290
23	12W 5N	C	5.5	<6
24	14W 10N	Ae	5.5	<6
25	20W 9+75N	B	5.5	<7
26	20W 1+25N	C	5.5	160
27	12W 9N	C	5.5	<8
28	20W 4+30S	B	5.5	10
29	20W 6+50S	C	5.5	180
7-30	14W 7+20N	Ae	5.5	<6
31	20W 6+50N	B	5.5	<6
32	14W 10N	B	5.5	<6
33	14W 8N	C	5.5	12
34	14W 8N	B	5.5	<6
35	14W 6N	B	5.5	<6
36	Control		5.5	290
37	rock		8.0	130
7-38	"		8.0	140

Sample set #8

Vial Number	Sample Description	Weight (grams)	Gold (ppb)
8-1	#1 Heavies	14.31	75
8-2	Mag	1.29	<50
8-3	effluent A	6.68	<5
8-4	" B	7.26	<5
8-5	" C	6.40	<5
8-6	#5 Heavies	2.93	1600
8-7	Mag	0.50	50
8-8	effluent A	5.56	59
8-9	" B	5.74	354
8-10A	" C	5.83	354
8-10B	control 310 ppb	8.56	270
8-11	L34 SN B	6.88	<5
8-12	SN C	6.33	<5
8-13	1+50N C	7.37	<5
8-14	3+50N C	7.22	<5
8-15	8+75N B	7.13	<5
8-16	SN Ae	7.02	<5
8-17	8+75N C	6.19	<5
8-18	3+30N C	6.61	<5
8-19		6.61	<5
8-20	Control 310 ppb	7.48	390
8-21	#1 -10 mesh	12.45	<5
8-22	"	12.32	<5
8-23	"	10.76	<5
8-24	#5 -10 mesh	10.73	14
8-25	"	10.93	9
8-26	"	10.10	7
8-27	Control	6.04	330

Sample Set #9

Vial Number	Sample Description	Weight (grams)	Gold (ppb)
9-1	#5 HMC -63 um	0.23	---
2	Kidd +63	1.10	4400
3	Creek +125	1.50	420
4	+125	1.00	970
5	+125	0.30	82
6	Lab +250	0.20	260
7	+250	0.10	10000
8	+500	1.80	<5
9	+1000	2.20	<5
10	LLT -63	2.20	<5
11	+63	1.30	<5
12	+125	2.70	<5
13	+250	1.00	<5
14	+500	2.40	<5
15	+1000	0.05	31
16	MAG +1000	----	---
17	+500	0.04	25
18	+250	----	---
19	+125	0.65	5
20	+63	0.32	6
21	-63	0.05	31
22	#5 HMC +1000 um	0.10	170
23	+500	0.13	1300
24	O.B. +250	0.56	2400
25	Lab +125	0.61	2200
26	+63	0.31	17000
27	-63	0.06	22000
28	LLT +1000	----	---
29	+500	0.10	6
30	+250	2.40	---
31	+125	1.90	<5
32	+125	2.20	<5
33	+125	2.20	<5
34	+63	1.10	220
35	-63	0.01	26000
36	MAG +1000	----	---
37	+500	0.01	<5
38	+250	0.20	<5
39	+125	0.30	13
40	+63	0.10	<7
41	-63	0.01	60
42	-10 +1000	0.50	9
43	TLS +500	0.30	27
44	+250	0.50	12
45	+125	0.40	360
46	+63	0.55	13
47	-63	1.20	16
48	#1 HMC +1000 um	----	---
49	+500	----	-

50	K.C.		+250	0.30		9
51	Lab		+125	1.90		34
52			+63	1.60		5
53			-63	0.30		42
54		LLT	+1000	0.10		70
55			+500	0.10		25
56			+250	4.50		[illegible]
57			+125	2.80		[illegible]
58			+125	2.30		[illegible]
59			+125	0.70		[illegible]
60			+63	2.20		[illegible]
61			+63	2.20		[illegible]
62			-63	0.56		1300
63		MAG	+1000	----		---
64			+500	0.03		1000
65			+250	0.12		[illegible]
66			+125	0.55		[illegible]
67			+63	0.60		[illegible]
68			-63	0.23		[illegible]
69	#1	HMC	+1000 um	0.01		[illegible]
70			+500	0.04		28
71	O.B.		+250	0.60		59
72	Lab		+125	2.10		[illegible]
73			+63	1.80		[illegible]
74			-63	0.30		5100
75	#1	LLT	+1000 um	0.03		44
76			+500	0.13		[illegible]
77	K.C.		+250	2.20		[illegible]
78	Lab		+125	2.30		[illegible]
79			+63	2.20		[illegible]
80			-63	1.80		250
81	#1	LLT	+1000 um	0.20		[illegible]
82			+500	0.80		6
83	O.B.		+250	2.20		[illegible]
84	Lab		+125	2.40		[illegible]
85			+63	2.10		[illegible]
86			-63	1.60		150
87	#5	LLT	+1000 um	0.04		7
88			+500	0.30		15
89	O.B.		+250	2.00		23
90	Lab		+125	2.00		11
91			+63	2.10		[illegible]
92			-63	0.16		13000

Sample Set #10

Vial Number	Sample Description			Weight (grams)	Gold (ppb)
10-1	#306	HMC	+1000	0.17	28000
2			+500	0.18	31000
3			+250	1.66	48000
4			+125	2.22	66000
5			+63	1.50	150000
6			-63	0.38	1100000
7		MAG,	ALL FRACTIONS	0.16	1100
8		LLT	+1000	0.08	1000
9			+500	0.16	2400
10			+250	2.24	310
11			+250	1.67	740
12			+250	9.30	850
13			+125	6.89	980
14			+63	9.96	2700
15			-63	1.22	9700
16	#84	HMC	+250	0.32	20
17			+125	2.10	130
18			+63	1.97	3200
19			-63	0.46	18000
20		MAG,	+250	0.72	12
21			+125	1.81	18
22			+63	1.15	25
23			-63	0.30	17
24		LLT	+250	0.17	76
25			+125	6.09	61
26			+63	8.90	91
27			-63	1.04	150
28	#CP	HMC	+1000	0.04	40
29			+500	0.46	39
30			+250	2.31	43
31			+125	2.53	60
32			+125	1.56	71
33			+63	2.99	3200
34			-63	1.00	1200
35		MAG	+500	0.26	[illegible]
36			+250	0.25	7
37			+125	1.20	12
38			+63	0.97	6
39			-63	0.24	14
40		LLT	+1000	0.19	[illegible]
41			+500	0.22	10
42			+250	2.21	9
43			+250	0.95	[illegible]
44			+125	7.20	[illegible]

45			+125	8.89	<10
46			+63	9.57	28
47			-63	2.07	83
48			-63	1.56	150
49	ϕLT	HMC	+500	0.33	64
50			+250	1.23	19
51			+125	2.52	19
52			+125	1.19	23
53			+63	2.30	550
54			+63	1.37	310
55			-63	1.30	1100
56		MAG	+500	0.40	<10
57			+250	0.47	38
58			+125	0.89	20
59			+63	0.94	17
60			-63	0.35	16
61		LLT	+1000	0.31	10
62			+500	0.24	8
63			+250	1.53	<10
64			+125	2.24	<5
65			+125	1.91	<5
66			+125	1.13	<5
67			+63	6.83	<10
68			-63	2.43	31
69	ϕ133	HMC	+1000	0.53	22000
70			+500	2.96	7700
71			+250	1.49	6300
72			+250	3.39	7400
73			+125	2.24	5800
74			+63	2.00	7300
75			-63	0.40	62000
76		MAG	ALL FRAC	0.30	1600
77		LLT	+1000	0.12	340
78			+500	0.18	620
79			+250	2.38	250
80			+125	9.33	120
81			+125	10.00	160
82			+125	2.21	140
83			+63	10.00	150
84			+63	8.65	310
85			-63	4.49	910
86	ϕ223	HMC	ALL FRAC	0.86	37000
87		MAG	ALL FRAC	0.01	250
88		LLT	+500	0.19	94
89			+250	2.33	20
90			+250	2.55	13
91			+250	1.23	12
92			+125	10.89	130
93			+125	11.49	110
94			+125	5.31	70
95			+63	11.30	180
96			+63	11.37	370
97			+63	1.58	430
98			-63	9.43	1400
99	ϕ306	LLT		9.97	1600
100	ϕ84	LLT		9.57	34
101	ϕ133	LLT		9.04	150
102	ϕ223	LLT		9.53	250
103	CP	LLT		10.60	44
104	LT	LLT		10.38	30
105	ϕ306	TL		7.07	1700
106		TL		8.40	1900
107		TL		7089	1600
108	ϕ84	TL		8.43	45
109		TL		8.33	63
110		TL		9.04	43
111	ϕ133	TL		8.30	190
112		TL		7.80	170
113		TL		8.32	170
114	ϕ223	TL		7.96	110
115		TL		7.90	89
116		TL		9.04	81
117	CP	TL		10.12	10
118		TL		9.81	14
119		TL		9.90	9
120	LT	TL		10.40	7
121		TL		10.52	11
122		TL		10.40	9
123	CP	LLT	+1000	8.94	7
124			+500	10.00	9
125			+500	9.95	<10
126			+500	9.64	15
127			+250	9.16	12
128			+125	8.56	10
129			+125	8.52	21
130			+125	8.68	13
131			+63	7.30	9
132	CONTROL		310 PPB	7.46	240
133			+63	6.20	34
134			+63	6.51	20

135	CYCL	2	8.40	180
136		1	8.10	240
137		1	7.83	360
138		2	8.10	62
139		3	6.94	24
140		3	7.46	28
141		3	6.52	22
142	CONTROL 310 PPB		6.90	270
143		4	5.65	26
144		5	5.88	22
145		5	5.48	18
146		5	5.36	22
147	EFFLUENT		3.92	320
148		"	4.07	270
149		"	4.14	250
150	CONTROL 310 PPB		7.81	220
151	#3 HMC	-63	0.23	21000
152		+250	2.41	7
153	LT LLT	+1000		7
154		+500		110
155		+250		17
156		+250		7
157		+250		9
158		+125		14
159		+63		32
160		+63		13
161		+63		16
162	CONTROL 310 PPB			240
163		-63		37
164	CYCL	1		90
165		1		19
166		5		15
167	CONTROL 310 PPB			240
168		5		14
169		2		22
170		5		11
171		1		86
172	CONTROL 310 PPB			290
173		4		14
174		3		10
175		3		12
176		1		73

Sample set #11

Vial Number	Sample Description	Weight (grams)	Gold (ppb)
1	#306	11.08	4200
2	"	10.90	4300
3	"	11.33	5300
4	#84	10.30	110
5	"	10.59	200
6	"	10.40	210
7	Control 310 ppb	8.80	270
8	#133	9.86	670
9	"	9.55	250
10	"	9.77	380
11	#223	10.36	470
12	"	11.34	540
13	"	11.29	510
14	CP	11.38	76
15	CP	11.57	29
16	CP	11.76	16
17	control	8.80	300
18	LT	11.33	21
19	LT	10.92	9
20	LT	11.42	20
21	LT effluent	4.49	35
22	"	3.69	40
23	"	3.83	27

Sample set #12

Vial Number	Sample Description	Weight (grams)	Gold (ppb)
12-1	#306 HMC	4.84	100000
2	MAG	0.20	40
3	LLT	10.90	1700
4	LLT	11.28	3100
5	LLT	11.30	2800
6	CONTROL 310 PPB	7.34	260
7	#133 HMC	14.00	11000
8	MAG	0.06	980
9	LLT	9.84	520
10	LLT	9.33	440

11		LLT	10.11	360
12	CONTROL 310 PPB		7.92	250
13	#84	HMC	2.77	1500
14		MAG	2.45	20
15		LLT	9.90	210
16		LLT	9.50	170
17		LLT	10.20	130

SAMPLE SET #13

Vial Number	Sample Description	Weight (g)	Gain (ppm)
1	#306 cycl 1	5.78	25000
2	cycl 2	6.84	3000
3	cycl 2	6.43	4400
4	cycl 3	6.38	2200
5	cycl 3	6.00	2200
6	cycl 3	6.75	2100
7	cycl 4	5.34	1500
8	cycl 4	5.62	1400
9	Sarm 7	7.80	290
10	cycl 5	4.83	780
11	cycl 5	5.13	820
12	cycl 5	4.72	460
13	effluent	5.68	310
14	effluent	4.50	320
15	effluent	4.75	260
16	Sarm 7	7.61	260
17	#84 cycl 1	6.80	230
18	cycl 1	7.70	180
19	cycl 1	7.70	260
20	cycl 2	6.90	100
21	cycl 2	7.27	160
22	cycl 2	7.32	120
23	cycl 3	5.97	150
24	cycl 3	6.22	150
25	cycl 3	6.25	120
26	Sarm 7	6.03	230
27	cycl 4	5.50	160
28	cycl 4	5.94	160
29	cycl 4	5.26	170
30	cycl 5	4.60	190
31	cycl 5	4.37	180
32	#133 cycl 1	7.99	1000
33	cycl 1	7.13	810
34	cycl 2	7.41	150
35	cycl 2	7.97	140
36	cycl 2	7.55	190
37	cycl 3	6.79	150
38	cycl 3	7.05	160
39	cycl 3	7.44	150
40	SARM 7	6.98	290
41	cycl 4	5.87	160
42	cycl 4	6.61	170
43	cycl 4	6.32	160
44	cycl 5	5.33	230
45	cycl 5	4.83	260
46	cycl 5	5.07	210
47	#306 <63 um	4.25	2800
48	<63 um	4.73	2400
49	#84 <63 um	5.73	160
50	<63 um	6.33	150
51	#133 <63 um	6.14	380
52	<63 um	6.68	330

Sample Set #14

Vial Number	Sample Description	Weight (grams)	Gold (ppb)
1	#84, cycl effluent	.94	170
2	"	.83	180
3	"	.87	180
4	#133, cycl effluent	.89	360
5	"	.88	400
6	"	.90	360
7	#84,NMHC, 2+1mm and 1+500um	.40	97
8	500+250um	.70	200
9	+125um	1.06	6900
10	+63um	.85	8600
11	-63um	.10	27000
12	MAGN, 2+1mm and 1+500um	.32	36
13	+250um	1.54	29
14	+125um	1.57	31
15	+63um	.88	43
16	-63um	.12	39
17	L.Lights, 2+1mm	.76	62
18	1+500um	1.76	25
19	+500um	.64	40
20	+250um	9.57	41
21	+125um	10.53	110
22	+63um	3.23	100
23	-63um	.13	130
24	#306,NHMC, +1mm	.33	140000
25	+500um	.94	50000
26	+250um	2.10	50000
27	+125um	1.97	64000
28	+63um	1.25	88000
29	-63um	.12	720000
30	MAGN,all fractions	.23	1800
31	L.Lights, +1mm	.65	1500
32	+500um	.80	1200
33	+250um	9.63	600
34	+125um	9.37	660
35	+125um	4.30	1300
36	+63um and -63um	3.10	4500
37	#133,NHMC, +1mm and +500um	.55	17000
38	+250um	5.33	13000
39	+125um	4.21	8700
40	+63um and -63um	1.41	9900
41	MAGN, all fractions	.87	1100
42	L. Lights, +1mm	.33	260
43	+500um	3.15	260
44	+250um	9.35	280
45	+125um	9.45	200
46	+63um and -63um	1.62	720
47	#5,NHMC, +1mm	.53	480
48	Control	1.33	180
49	+500um	.61	600
50	+250um	.75	260000
51	+125um	.49	5100
52	+63um and -63um	3.80	1000
53	MAGN, all fractions	1.01	[illegible]
54	Control	1.74	230
55	L. Lights, +1mm	.48	[illegible]
56	+500um	1.66	[illegible]
57	+250um	7.47	9
58	+125um	4.80	48
59	+63um and -63um	2.11	55
60	Control	1.66	770
61	Table L,#5, +1mm	9.63	8
62	"	9.30	5
63	"	6.10	23
64	+500um	9.33	13
65	+500um	8.20	7
66	+250um	7.76	6
67	"	2.90	5
68	+125um	3.35	18
69	+63um and -63um	1.40	850
70	Table L,#306, +1mm	6.75	1700
71	"	5.54	3200
72	+500um	7.10	2000
73	"	2.10	1400
74	+250um	3.06	1300
75	"	6.28	1600
76	+125um	8.63	1400
77	"	1.07	1300
78	+63um	2.80	2200
79	-63um	.45	3500
80	Control	1.30	210

81	Table L,#84, +1mm		8.48	55
82	"		5.67	60
83	+500um		6.53	120
84	"		5.86	130
85	+250um		8.38	110
86	"		5.78	110
87	+125um		7.57	400
88	"		5.62	290
89	+63um		4.22	170
90	-63um		1.00	210
91	Control		1.56	220
92	Table L,#133, +1mm		8.51	280
93	"		7.46	240
94	"		6.53	320
95	+500um		6.88	360
96	"		9.52	320
97	+250um		9.44	260
98	"		10.30	320
99	+125um		9.18	290
100	+63um		5.00	230
101	-63um		1.28	300
102	Control		1.60	210
103	Bulk Table Lights,	#5	10.40	8
104		#5	11.40	29
105		#306	9.10	2300
106		#306	9.10	1900
107		#84	10.50	
108		#84	9.60	94
109		#133	10.30	310
110		#133	10.60	260

Sample Set #15

Vial Number	Sample Description		Weight (grams)	Gold (ppb)
15-1	Owl Creek	OT-00207 (-63um)	6.52	6
2	Sonic Core	207	6.10	5
3		207	5.30	[illegible]
4		208	6.92	13
5		208	7.36	43
6		209	5.00	11
7		209	6.10	16
8		209	2.92	[illegible]
9		210	6.30	20
15-10		210	6.60	38
11		210	3.50	20
12	Control-310 ppb		7.30	390
13		211	4.60	[illegible]
14		211	3.50	7
15		212	3.70	11
16		212	6.30	5
17		212	5.50	7
18		213	4.70	6
19		213	4.90	9
15-20		213	5.20	8
21		223	8.60	7
22		223	7.70	[illegible]
23		223	4.90	50
24		215	3.95	6
25		215	4.00	7
26		215	4.70	7
27	Control-310 ppb		6.80	340
28		216	5.50	29
29		216	6.50	26
15-30		216	7.10	29
31		217	4.70	[illegible]
32		217	4.43	[illegible]
33		217	4.90	5
34		218	4.55	8
35		218	5.50	[illegible]
36		218	5.80	6
37		220	6.95	8
38		220	6.25	10
39		220	7.30	5
15-40		219	6.25	23
41		219	6.20	10
42		219	5.95	14
43	Standard	214	6.40	200
44	"	214	6.15	200
45	Standard	214	6.50	210

46			222	6.10	6
47			222	6.70	5
48			222	6.30	6
49		Control-310 ppb		7.50	330
15-50		Standard	230	8.20	320
51		"	230	7.15	330
52		Standard	230	8.20	310
53			224	5.05	10
54			224	5.80	7
55			224	6.45	5
56			225	4.00	14
57			225	5.40	7
58			226	5.20	7
59			226	5.80	17
15-60			226	4.70	10
61			227	5.15	15
62			227	5.90	9
63			227	5.20	10
64		Standard	229	5.90	190
65		"	229	5.85	190
66		Standard	229	5.30	190
67			228	5.55	25
68			228	6.15	23
69			228	5.30	39
15-70		Standard	221	7.10	350
71		"	221	7.40	310
72		Standard	221	7.05	300
73			231	5.70	28
74			231	6.90	70
75		Control-310 ppb		8.55	300
76	Sample #5	, NMHC	, +1000 and +500um	0.30	7700
77	X-Ray Assay		+250um	1.00	2200
78			+125um	0.93	40000
79			+63 and -63um	0.64	600000
15-80		Lights	, +2000um	0.40	20
81			+500um	0.23	70
82			+250um	6.00	130
83			+125um	7.20	1700
84			+63um	1.05	10000
85		Magnetics	, all fractions	1.10	1400
86	McBean	(-63um)	350 (#1)	8.10	15
87	Ultrasonic		"	8.35	7
88	Separation		350 (#1)	8.10	5
89			352 (#3)	7.43	7
15-90			"	7.10	10
91			352 (#3)	8.35	9
92			351 (#2)	8.00	10
93			"	8.50	8
94			351 (#2)	8.15	5
95		Control-310 ppb		7.90	320
96	McBean	(-63um)	350 (#1)	6.60	15
97	Motar and Pestle		350 (#1)	5.90	8
98	Separation		350 (#1)	3.90	20
99			352 (#3)	6.20	45
15-100			352 (#3)	7.10	10
101	Sample 306	, NMHC	,+500 and +250um	0.36	120000
102	X-Ray Assay		+125um	0.53	380000
103			+63 and -63um	0.22	190000
104		Light	,+1000,+500,+250um	3.25	3500
105			+125um	3.10	7000
106			+63	0.88	18000
107		Magnetics	, all fractions	0.08	17000
108		Control-310 ppb		1.45	320

Sample Set Number 16

Vial Number	Sample	Weight (grams)	Gold (ppb)
16-1	#5, bulk -63um	6.40	82
2	"	5.94	62
3	"	5.33	42
4	cycl. #1	3.90	2000
5	cycl. #2	9.97	110
6	cycl. #3	6.35	120
7	"	9.20	84
8	"	8.20	78
9	cycl. #4	7.40	75
16-10	"	8.10	81
11	"	7.56	84
12	cycl. #5	6.70	52
13	"	6.94	56
14	"	7.24	60
15	control 310 ppb	8.72	380
16	effluent	5.30	31
17	"	4.60	36
18	"	5.63	30
19	#223, cycl. #1	5.10	1000
16-20	cycl. #2	8.50	130
21	"	8.85	170
22	"	9.15	170
23	control 310 ppb	7.70	560
24	cycl. #3	8.20	110
25	"	3.50	100
26	"	8.00	99
27	cycl. #4	7.55	97
28	"	7.25	100
29	"	7.90	89
16-30	cycl. #5	6.20	120
31	"	6.40	110
32	"	6.05	110
33	effluent	6.00	170
34	"	6.00	180
35	"	5.90	170
36	control 310 ppb	8.45	380
37	bulk -63um	6.50	140
38	"	6.55	190
16-39	"	7.72	160

Sample Set #18

Vial Number	Sample		Weight (grams)	Gold (ppb)
18-1	#306, Vial #10-105,	+1000um	2.35	2700
2	Table Lights	+500um	2.10	1500
3		+250um	1.80	2200
4		+125um	0.40	2900
5		+63 & -63um	0.23	4000
6	Control 310 ppb		7.90	320
7	Vial #10-106,	+1000um	1.70	4200
8		+500um	1.90	2400
9		+250um	2.20	2500
18-10		+125um	1.30	1400
11		+63um	0.80	720
12		-63um	0.30	1800
13	Control 310 ppb		7.60	280

Sample Set 19

Vial Number	Sample Description		Weight (grams)	Gold (ppb)
19-1	85, -6 + 10 mesh,	Lights	1.60	40
-2		Interm.,NMHMC	0.53	20
-3		Heavies,NMHMC	0.18	3800
-4	-10+18 mesh,	Lights	8.33	30
-5		"	8.44	40
-6		"	8.40	30
-7		"	8.94	30
-8		Lights	9.20	30
-9		Interm.,NMHMC	2.82	30
19-10		Heavies,NMHMC	1.56	230
-11	Control 310 ppb		8.70	350
-12	-32+60 mesh,	Lights	9.10	30
-13		"	9.20	30
-14		"	9.10	30
-15		"	9.35	30
-16		Lights	9.30	30
-17	-60+115 mesh,	Lights	8.00	20
-18		"	8.10	20
-19		"	8.20	20
19-20		"	7.90	30
-21		Lights	7.10	30
-22	Control 310 ppb		7.90	380
-23	-32+60 mesh,	Interm.,NMHMC	4.23	40
-24	-60+115 mesh,	Interm.,NMHMC	4.03	30
-25	-32+60 mesh,	Heavies,NMHMC	2.02	25000
-26	-60+115 mesh,	Heavies,NMHMC	1.30	13000
-27	-115+250 M,	Lights	7.90	20
-28		"	7.94	50
-29		"	8.10	20
19-30		"	8.25	70
-31		Lights	8.43	70
-32	-250 M,	Lights	5.65	210
-33		Lights	5.15	210
-34	-115+250 M,	Interm.,NMHMC	6.55	60
-35	-250 M,	Interm.,NMHMC	1.30	20
-36		Interm.,NMHMC	1.44	80
-37	-115+250 M,	Heavies,NMHMC	0.97	3700
-38	-250 M,	Heavies,NMHMC	1.15	1900
-39	+.5 um clay		4.60	40
19-40	"		4.70	20
-41	+.5 um clay		4.60	20
-42	-.5um clay		5.70	50
-43	"		5.50	40
-44	-.5um clay		5.40	60
-45	Control 310 ppb		8.80	350
-46	#306,-6+10 M,	Lights	5.73	100
-47		Lights	3.90	120
-48		Interm.,NMHMC	2.44	7100
-49		Heavies,NMHMC	2.46	20000
19-50	-10+18 M,	Lights	7.20	580
-51		"	7.10	1000
-52		"	7.20	780
-53		"	7.00	810
-54		Lights	7.30	790
-55		Interm.,NMHMC	9.65	7900
-56		Interm.,NMHMC	7.70	8500
-57	-18+32 M,	Interm.,NMHMC	9.30	6200
-58		Interm.,NMHMC	8.70	7100
-59		Heavies,NMHMC	11.05	31000
19-60		"	9.92	47000
-61		Heavies,NMHMC	4.30	48000
-62	-32+60 M,	Lights	8.00	520
-63		"	8.13	470
-64		"	8.10	360
-65		"	8.00	550
-66		"	8.00	460
-67		Lights	7.95	480
-68	-60+115 M,	Lights	8.66	730
-69		"	8.40	660
19-70		"	8.50	620
-71		"	7.90	880
-72		Lights	7.00	930
-73	Control 310 ppb		8.00	310
-74	-32+60 M,	Interm.,NMHMC	8.60	5300
-75		Interm.,NMHMC	9.00	4200
-76	-60+115 M,	Interm.,NMHMC	7.40	1100
-77		"	7.40	1500
-78		"	7.65	1300
-79		Interm.,NMHMC	0.90	1000
19-80	-32+60 M,	Heavies,NMHMC	9.44	55000
-81	-60+115 M,	Heavies,NMHMC	3.90	73000
-82	-115+250 M,	Lights	8.50	1400
-83		"	8.55	1200
-84		Lights	8.55	1000
-85	-250 M ,	Lights	6.70	14000
-86	-115+250 M,	Interm.,NMHMC	7.90	920

-87			"	8.20	780
-88			"	8.00	990
-89			"	8.70	1000
19-90			Intera.,NMHMC	3.40	1700
-91	-250 M,		Intera.,NMHMC	1.50	15000
-92	-115+250 M,		Heavies,NMHMC	3.67	100000
-93	-250 M,		Heavies,NMHMC	0.50	190000
-94	Control 310 ppb			8.20	340
-95	+.5um clay			4.71	1300
-96	"			3.90	1400
-97	+.5um clay			4.53	1300
-98	-.5um clay			5.45	1500
-99	"			5.62	1600
19-100	-.5um clay			5.60	1500
-101	Control 310 ppb			8.05	320
-102	#133,-6+10 M,	Lights		8.45	260
-103		"		8.20	360
-104		Lights		8.10	270
-105		Intera. and Heavies		0.10	110
-106	-10+18 M,	Lights		8.40	240
-107		"		7.50	330
-108		"		8.30	1200
-109		"		8.55	240
19-110		Lights		8.20	220
-111		Intera.,NMHMC		0.15	1800
-112		Heavies,NMHMC		0.60	13000
-113	-32+60 M,	Lights		9.10	220
-114		"		8.70	240
-115		"		9.00	260
-116		"		9.20	220
-117		Lights		9.00	310
-118	-60+115 M,	Lights		8.50	190
-119		"		8.90	200
19-120		Lights		7.90	240
-121	-32+60 M,	Intera.,NMHMC		7.05	2200
-122		Intera.,NMHMC		3.50	1600
-123	-60+115 M,	Intera.,NMHMC		7.30	380
-124		"		7.15	380
-125		Intera.,NMHMC		8.50	410
-126	-32+60 M,	Heavies,NMHMC		4.14	310
-127	-60+115 M,	Heavies,NMHMC		3.64	11000
-128	-115+250 M,	Lights		8.30	210
-129		"		8.30	200
19-130		"		8.10	170
-131		Lights		6.75	150
-132	-250 M,	Lights		6.50	570
-133	Control 310 ppb			6.70	280
-134	-115+250 M,	Intera.,NMHMC		8.20	310
-135		"		8.60	290
-136		"		9.10	240
-137		"		8.55	240
-138		"		8.80	260
-139		"		8.05	270
19-140		Intera.,NMHMC		5.00	270
-141	-250 M,	Intera.,NMHMC		4.80	710
-142	-115+250 M,	Heavies,NMHMC		2.44	5300
-143	-250 M,	Heavies,NMHMC		0.27	76000
-144	+.5um clay			2.90	340
-145	-.5um clay			7.02	300
-146	"			6.90	340
-147	-.5um clay			7.65	320
-148	#84,-6+10 M,	Lights		8.33	30
-149		"		9.20	30
19-150		"		9.05	20
-151		Lights		8.70	40
-152		Intera.		2.15	430
-153		Heavies		0.18	40
-154	-10+18 M,	Lights		9.50	40
-155		"		9.25	70
-156		"		9.35	50
-157		"		9.10	40
-158		Lights		9.45	40
-159	-18+32 M,	Lights		8.85	50
19-160		"		8.70	30
-161		"		9.00	60
-162		"		8.90	70
-163		Lights		9.05	60
-164	-32 M,	Lights		6.50	170
-165	Control 310 ppb			7.30	350
-166	-10+18 M,	Intera.,NMHMC		1.50	420
-167	-18+32 M,	Intera.,NMHMC		2.91	30
-168	-32 M,,	Intera.,NMHMC		0.14	80
-169	-10+32 M,	Heavies,NMHMC		0.54	180
19-170	-32+60 M,	Lights		8.80	90
-171		"		8.10	90
-172		"		8.65	110
-173		"		8.80	60
-174		Lights		8.30	120
-175	-60+115 M,	Lights		8.70	120

-176		"		8.90	100
-177		"		8.20	120
-178		Lights		6.50	90
-179	-32+60 M,	Interm.,NNHMC		4.45	50
19-180	-60+115 M,	Interm.,NNHMC		4.10	90
-181	-32+60 M,	Heavies,NNHMC		0.52	50
-182	-60+115 M,	Heavies,NNHMC		0.40	70
-183	-115+250 M,	Lights		8.50	90
-184		"		8.40	90
-185		"		9.00	90
-186		"		8.70	160
-187		Lights		9.10	150
-188	-250 M,	Lights		6.30	150
-189		Lights		5.20	170
19-190	-115+250 M,	Interm.,NNHMC		7.73	90
-191		Interm.,NNHMC		4.71	140
-192	-250 M,	Interm.,NNHMC		2.50	180
-193	-115+250 M,	Heavies,NNHMC		0.70	3600
-194	-250 M,	Heavies,NNHMC		0.19	5400
-195	Control 310 ppb			6.70	340
-196	+.5um clay			0.22	600
-197	-.5um clay			7.20	330
-198	"			6.80	350
-199	-.5um clay			7.10	340
19-200	#5,-18+32 M,	Lights		9.30	30
-201		"		9.40	30
-202		"		9.25	20
-203		"		9.40	20
-204		Lights		9.10	120
-205	#306,-18+32 M,	Lights		6.90	200
-206		"		6.50	250
-207		"		7.00	230
-208		"		7.25	580
-209		Lights		7.10	530
19-210	#133,-18+32 M,	Lights		8.00	280
-211		"		8.20	290
-212		"		8.20	260
-213		"		8.40	270
-214		Lights		8.20	240
-215	#5,-10+32 M,	Interm., Mas. Frac		0.56	120
-216		Heavies, Mas. Frac		0.32	20
-217	-32+60 M,	Interm., Mas. Frac		0.17	120
-218		Heavies, Mas. Frac		0.64	30
-219	-60+115 M,	Heavies, Mas. Frac		0.64	140
19-220	-115+250 M,	Heavies, Mas. Frac		0.33	20
-221	#306,-115+250 M,	Heavies, Mas. Frac		0.10	330
-222	#84,-10+18 M,	Interm., Mas. Frac		0.10	90
-223	-18+32 M,	Interm., Mas. Frac		0.40	30
-224	-10+32 M,	Heavies, Mas. Frac		0.12	140
-225	-32+60 M,	Interm., "		0.20	40
-226	-60+115 M,	Interm., "		0.10	100
-227	-32+60 M,	Heavies, "		0.90	20
-228	-60+115 M,	Heavies, "		0.80	30
-229	-115+250 M,	Heavies, "		0.70	200
19-230	-250 M,	Heavies, "		0.08	4400
-231	#5,-18+32 M,	Interm.,NNHMC		3.52	50
-232		Heavies,NNHMC		1.70	1200
-233	#133,-18+32 M,	Interm.,NNHMC		2.51	2200
-234	Control 310 ppb			7.00	330

Sample Set # 20

Vial Number	Sample Description	Weight (grams)	Gold (ppb)
20-1	#5, NNHMC , +1000 um	0.10	210
-2	+500	0.40	200
-3	+250	0.70	160000
-4	+125	0.50	8200

-5		+63	0.36	58000
-6		-63	0.03	99000
-7	Mag, all fractions		0.95	12
-8	Control 310 ppb		1.36	200
-9	L. L.,	+1000	0.85	8
20-10		+500	3.60	28
-11		+250	8.33	30
-12		+250	3.77	18
-13		+125	8.00	79
-14		+63	1.30	22
-15		-63	0.01	360
-16	#223, NHMC,	+1000	0.03	9700
-17		+500	0.50	7100
-18		+250	2.48	24000
-19		+125	1.24	11000
20-20		+63	0.50	65000
-21		-63	0.03	1000000
-22	Control 310 ppb		1.26	260
-23	L. L.,	+1000	0.03	1800
-24		+500	0.24	140
-25		+250	7.73	1100
-25A		+250	3.27	2000
-26		+125	8.17	62
-27		+63	2.10	2800
-28		-63	0.05	31000
-29	Mag, all fractions		0.04	990
20-30	#5, Table Lights,	+1000	9.33	16
-31		"	9.20	13
-32		"	9.33	8
-33		"	9.20	12
-34		"	9.30	19
-35		+1000	2.55	96
-36		+500	9.12	15
-37		"	9.16	7
-38		"	9.50	10
-39		"	8.87	5
20-40		+500	1.83	23
-41	Control 310 ppb		1.46	320
-42		+250	8.98	11
-43		"	8.90	15
-44		+250	6.32	11
-45		+125	7.00	12
-46		+125	3.05	15
-47		+63	7.73	550
-48		-63	5.82	450
-49		-63	4.10	470
20-50	#223, Table Lights,	+1000	8.57	260
-51		"	8.80	110
-52		"	9.00	520
-53		+1000	7.25	120
-54		+500	9.32	230
-55		"	9.22	75
-56		"	9.52	110
-57		"	8.05	120
-58		+500	4.17	170
-59		+250	8.87	340
20-60		"	9.20	230
-61		"	9.20	170
-62		"	9.47	300
-63		"	9.35	210
-64		+250	7.10	650
-65	Control 310 ppb		1.60	240
-66		+125	9.10	230
-67		"	8.55	270
-68		"	8.54	220
-69		+125	2.02	280
20-70		+63	7.11	300
-71		+63	2.68	320
-72		-63	5.93	860
-73		-63	1.90	840
-74	Control 310 ppb		1.44	

Sample Set 21

Vial Number	Sample Description		Weight (grams)	Gold (ppb)
21-1	Sonic Core	#224	5.63	24
-2	Owl Creek	#224	6.00	19
-3	-63 um	#224	4.30	67
-4		#251	5.40	110
-5		#251	5.85	51
-6		#251	5.92	<11
-7		#219	5.60	<10
-8		#219	5.74	<12

-9		#219	5.65	16
21-10		#219	5.45	11
-11		#222	6.00	10
-12		#222	5.90	10
-13		#222	5.90	9
-14		#208	5.97	35
-15		#208	6.20	15
-16		#208	6.10	9
-17	Control 310 ppb		1.60	310
-19	Standard #13-19 260 ppb		7.70	300
21-20	#5 NMHC	+1000um	0.04	190
-21		+500	0.23	90
-22		+250	0.75	1300
-23		+125	0.62	1500
-24		+63	0.32	1100
-25		-63	0.08	65000
-26	L.Lts	+1000	0.11	22
-27		+500	2.56	12
-28		+250	9.30	16
-29		+125	5.20	24
21-30		+63	1.51	27
-31		-63	0.16	140
-32	#5 Bulk L.Lts		9.10	14
-33	Standard #13-33 810 ppb		7.13	840
-34	#5 Bulk L.Lts		8.70	10
-35	#223 NMHC	+1000	0.05	3200
-36		+500	0.44	11000
-37		+250	2.00	5400
-38		+125	1.60	7000
-39		+63	0.60	65000
21-40		-63	0.06	490000
-41	L.Lts	+1000	0.24	98
-42		+500	0.65	220
-43		+250	4.80	330
-44		+125	6.35	350
-45		+125	5.06	320
-46		+63	4.03	1300
-47		-63	0.20	16000
-48	Standard #13-48 2400 ppb		4.73	2960
-49	#223 Bulk L.LTs		8.55	640
21-50	#223 Bulk L.Lts		8.72	1300
-52	#5 Table Lts	+1000	8.96	6
-53		"	9.27	6
-54		+1000	9.33	8
-55		+500	8.50	8
-56		"	9.45	11
-57		"	9.30	11
-58		+500	8.60	11
-59		+250	8.70	11
21-60		"	8.74	9
-61		+250	7.91	9
-62		+125	7.82	22
-63		+125	2.84	32
-64		+63	7.53	35
-65		-63	5.46	36
-66		-63	5.41	47
-67		-63	5.64	37
-68	#223 Table Lts	+1000	4.45	410
-69		+500	8.80	72
21-70		+500	3.30	110
-71	Standard #10-71 6300 ppb		2.96	4600
-72		+500	6.70	470
-81	Standard #10-81 160 ppb		10.00	160
-84	#5 NMHC Mas		0.70	15
-85	#223 NMHC Mas		0.05	11500
-86	#223 Table Lts	+250	9.00	97
-87		"	7.70	160
-88		+250	8.30	160
-89		+125	7.95	130
21-90		"	8.00	200
-91		+125	8.05	230
-92		+63	7.50	240
-93		+63	6.54	310
-94		+63	5.10	160
-95		-63	8.00	370
-96		-63	7.70	390

Sample Set Number 22
McBean Samples

Vial Number	Sample Description	Weight (grams)	Gold (ppb)
22-1	#310,HMC, +1000um	0.10	50
-2	+500	0.46	660
-3	+250	2.13	1000
-4	+125	7.30	670
-5	+63	4.32	490
-6	-63	1.14	1500
-7	MAG,all fractions	4.52	33
-8	#300,HMC, +1000um	0.13	1600
-9	+500	0.31	1600
22-10	+250	1.60	160
-11	+125	3.30	85
-12	+63	2.50	1100
-13	-63	0.60	1500
-14	MAG,all fractions	2.95	55
-15	STD,310 ppb	1.33	300
-16	#300,LIQ. LTS, +1000um	7.10	15
-17	+1000	5.00	10
-18	+500	10.10	65
-19	+250	10.25	65
22-20	"	11.57	65
-21	"	11.45	65
-22	"	11.74	65
-23	"	11.40	65
-24	"	11.30	65
-25	+250	10.01	65
-26	+125	12.00	65
-27	"	12.10	65
-28	"	11.80	65
-29	"	11.80	65
22-30	"	11.93	65
-31	"	11.40	65
-32	"	11.95	65
-33	"	12.00	65
-34	"	11.85	65
-35	"	12.55	65
-36	+125	11.40	65
-37	STD. 310 ppb	1.40	310
-38	+63	11.90	14
-39	+63	10.35	11
22-40	+63	5.36	42
-41	-63	6.00	300
-42	#310, LIQ. LTS, +1000um	10.02	220
-43	+500	8.75	65
-44	+500	5.60	77
-45	+250	11.63	65
-46	"	11.77	65
-47	"	11.54	65
-48	"	11.20	65
-49	"	8.15	65
22-50	+250	7.04	65
-51	+125	11.85	65
-52	"	11.20	65
-53	"	12.00	65
-54	"	11.90	65
-55	"	11.50	65
-56	"	11.86	65
-57	"	12.06	65
-58	"	11.60	65
-59	"	9.64	65
22-60	+125	8.50	65
-61	+63	11.00	65
-62	+63	9.04	13
-63	+63	4.93	41
-64	STD 310 ppb	5.65	320
-65	-63	6.16	83
-66	#300 Bulk Table Lights	11.30	65
-67	"	11.50	65
-68	"	11.70	65
-69	#310 Bulk Table Lights	11.44	7
22-70	"	11.14	65
-71	"	11.12	65

Sample Set #23

Vial Number	Sample Description			Weight (grams)	Gold (ppb)
23-01	Assayers	(20-3)	+250 um	0.70	120000
-02	#5	(20-4)	+125	0.50	5700
-03		(20-5)	+63	0.36	47000
-04		(20-6)	-63 um	0.03	72000
-05	O.B.M.	(21-22)	+250	0.75	760
-06	#5	(21-23)	+125	0.62	600
-07		(21-24)	+63	0.32	960
-08		(21-25)	-63	0.06	25000
-09	STD. 310ppb			1.46	190
-10	Assayers	(15-76)	+500 um	0.30	6600
23-11	#5	(15-77)	+250	0.10	1800
-12		(15-78)	+125	0.93	38000
-13		(15-79)	-125	0.64	570000
-14	STD. 7.5 ppm			1.75	14000
-15	C.F.M.	(19-10)	+1000 um	1.56	110
-16	#5	(19-232)	+500	1.70	720
-17		(19-25)	+250	2.02	21000
-18		(19-26)	+125	1.30	13000
-19		(19-37)	+63	0.97	3000
-20		(19-38)	-63	1.15	1600
23-21	STD. 310 ppb			1.35	190
-22	C.F.M.	(19-59)	+1000 um	11.05	29000
-23	#306	(19-60)	+500	9.92	44000
-24		(19-61)	+500	4.30	52000
-25		(19-80)	+250	9.44	47000
-26		(19-81)	+125	3.90	57000
-27		(19-92)	+63	3.67	82000
-28		(19-93)	-63	0.50	140000
-29	STD. 7.5 ppm			2.00	5800

Sample Set # 24

Vial Number	Sample Description		Weight (grams)	Gold (ppb)
24-1	Hemlo	#153, 10+00 S	2.20	30
2	Samples	#155, 0+00	6.05	2100
3	(12 W)	#157, 0+25 N	7.63	770
4		#159, 0+50 N	4.46	3700
5		#162, 1+00 N	4.30	7600
6		#165, 1+25 N	1.33	740000
7		#169, 1+00 S	6.40	6300
8		#170, 0+50 S	2.10	6500
9		#173, 2+75 N	5.10	52000
24-10	Standard CCU-1 7.5 ppm		1.80	7000
11	Standard CCU-1 7.5 ppm		1.05	6800

Sample Set # 25

Vial Number	Sample Description		Weight (grams)	Gold (ppb)
25-1	Hemlo	M.A.-2 std. 1.8 ppm	4.90	2300
2	Samples	#150, 16+00 S	3.60	480
3	(12 W)	#176B 6+00 N	6.20	12
4		#176C 7+00 N	7.60	28
5		#180B 9+10 N	8.40	21
6		M.A.-2 std. 1.8 ppm	5.30	1500
7		Standard 346 ppb	4.80	450

Sample Set Number 26

Vial Number	Sample Description	Weight (grams)	Gold (ppb)
26-1	13-51	6.1	45
2	13-52	5.0	7
3	13-53	6.0	9
4	13-54	5.9	6
5	13-55	6.0	7
6	13-56	6.0	15
7	13-57	6.1	11
8	14-48	1.3	220
9	14-60	1.7	340
26-10	14-80	1.3	300
11	14-91	1.6	340
12	14-102	1.6	270
13	15-12	7.3	320
14	15-27	6.8	310
15	15-49	7.5	270
16	15-75	8.6	280
17	15-95	8.0	230
18	15-108	1.5	230
19	16-15	8.8	270
26-20	16-23	7.7	430
21	16-36	8.5	250
22	20-8	1.4	220
23	20-22	1.3	290
24	20-41	1.5	420
25	20-65	1.6	280
26	20-74	1.5	230
27	20-17	1.6	240
28	Standard (346 ppb)	6.0	350
29	Rock samples	9.5	30
26-30	"	9.9	17
31	"	9.1	71
32	"	8.6	91
33	"	9.2	220
34	"	10.3	170
35	"	9.3	320
36	"	8.7	150
37	Standard (346 ppb)	6.0	320
38	Rock samples	9.8	<5
39	"	9.1	<5
26-40	"	8.7	7
41	"	8.7	<5
42	"	8.6	35
43	"	9.1	42
44	Standard (346 ppb)	6.0	350
45	Rock samples	9.4	<5
46	"	8.8	<5
26-47	"	10.1	5

APPENDIX D

GOLD CALCULATION

D.1 Calculation Of Total Gold Content

The total gold content of till samples was calculated by multiplying the gold concentration of the sample fraction times the weight of the fraction. The weight of the original sample, the weight of the plus 2 mm material and the weight of the minus 2 mm material is recorded prior to tabling. All fractions of the processed sample are weighed and recorded (the non-magnetic heavy mineral concentrate, the heavy liquid-light fraction and the table-light fraction). Each fraction is separated into six particle size fractions. A portion of each particle size fraction is analyzed for gold. The calculation is demonstrated by the following example.

Sample #5 Weight of original sample = 5 kg

Weight of plus 2 mm = 2 kg

Weight of minus 2 mm (table feed) = 3 kg

Weight of non-magnetic heavy mineral concentrate = 1.74 g

Weight of heavy liquid lights = 47.0 g

Weight of table lights = 2951 g

1) Non-magnetic heavy mineral concentrate:

Size Fraction (μm)	Weight Analyzed (g)	Gold Concentation (ppb)	Gold Weight (ng)
2000-1000	0.07	170	12
1000-500	0.13	1300	169
500-250	0.56	2400	1344
250-125	0.61	2200	1342
125-63	0.31	17000	5270
minus 63	0.06	22000	1320
Total	1.74		9457

The total contained gold is now normalized to 5 kg.

$$9457 \text{ ng times } \frac{5.0 \text{ kg}}{3.0 \text{ kg}} = 15{,}762 \text{ ng}$$

2) Heavy liquid light fraction

Size Fraction (μm)	Weight Analyzed (g)	Gold Concentation (ppb)	Gold Weight (ng)
2000-1000	n.a.	n.a.	
1000-500	0.11	6	0.66
500-250	2.41	7	17.00
250-125	6.33	<5	16.00
125-63	1.06	220	233.00
minus 63	0.01	26000	260.00
Total	9.92		527.00

Only 9.92 g of liqiud lights was analyzed out of a total of 47g. Therefore, the next step is to calculate the amount of gold in the total fraction.

$$527 \text{ ng times } \frac{47.00 \text{ g}}{9.92} = 2497 \text{ ng}$$

Now the gold content must be normalized to 5 kg.

$$2497 \text{ ng times } \frac{5 \text{ kg}}{3 \text{ kg}} = 4162 \text{ ng}$$

3) Table Lights

Size Fraction (um)	Weight Analyzed (g)	Gold Concentation (ppb)	Gold Weight (ng)
2000-1000	0.49	9	5.0
1000-500	0.29	27	8.0
500-250	0.45	12	5.0
250-125	0.44	360	158.0
125-63	0.55	13	7.0
minus 63	1.20	16	19.0
Total	3.42		202.0

Only 3.42 g of table lights was analyzed out of a total of 2951g. Therefore, the next step is to calculate the amount of gold in the total fraction.

$$202 \text{ ng times } \frac{2951 \text{ g}}{3.42} = 174298 \text{ ng}$$

Now the gold content must be normalized to 5 kg.

$$174298 \text{ ng times } \frac{5 \text{ kg}}{3 \text{ kg}} = 290498 \text{ ng}$$

The total contained gold in the original sample is equal to the sum total of all fractions.

Non-magnetic heavy mineral concentrate	=	15,762 ng
Heavy liquid light fraction	=	4,162 ng
Table light fraction	=	290,498 ng
Total		310,422 ng

APPENDIX E

METHYLENE IODIDE HEAVY LIQUID SEPARATION

E.1 EFFICIENCY OF THE HEAVY LIQUID SEPARATION

Methylene iodide was used to separate the table concentrate into a heavy liquid heavy fraction (heavy mineral concentrate) and a heavy liquid light fraction. The results from Owl Creek, discussed in the text, suggest that the separation process is variable for different particle sizes. This feature is also noted in the Hemlo, McBean Mine and Green Lake samples (Figures E.1-3).

In the case of sample #84, the heavy liquid separation is good for particles of a size smaller than 125 µm but, poor for particles larger than 125 µm (Figure E.1). The separation is good for all size fractions of sample #133.

The Green Lake samples show relatively good heavy liquid separation in all size fractions (Figure E.2).

The efficiency of the heavy liquid separation with particle size is variable in the McBean Mine samples (Figure D.3). Good separation is apparent in all size fractions of sample #300 except in the minus 63 µm fraction. Sample #310 shows the opposite with good separation in all fractions except in the coarsest fraction where a greater concentration is noted in the heavy liquid-light fraction than that in the heavy liquid- heavy fraction.

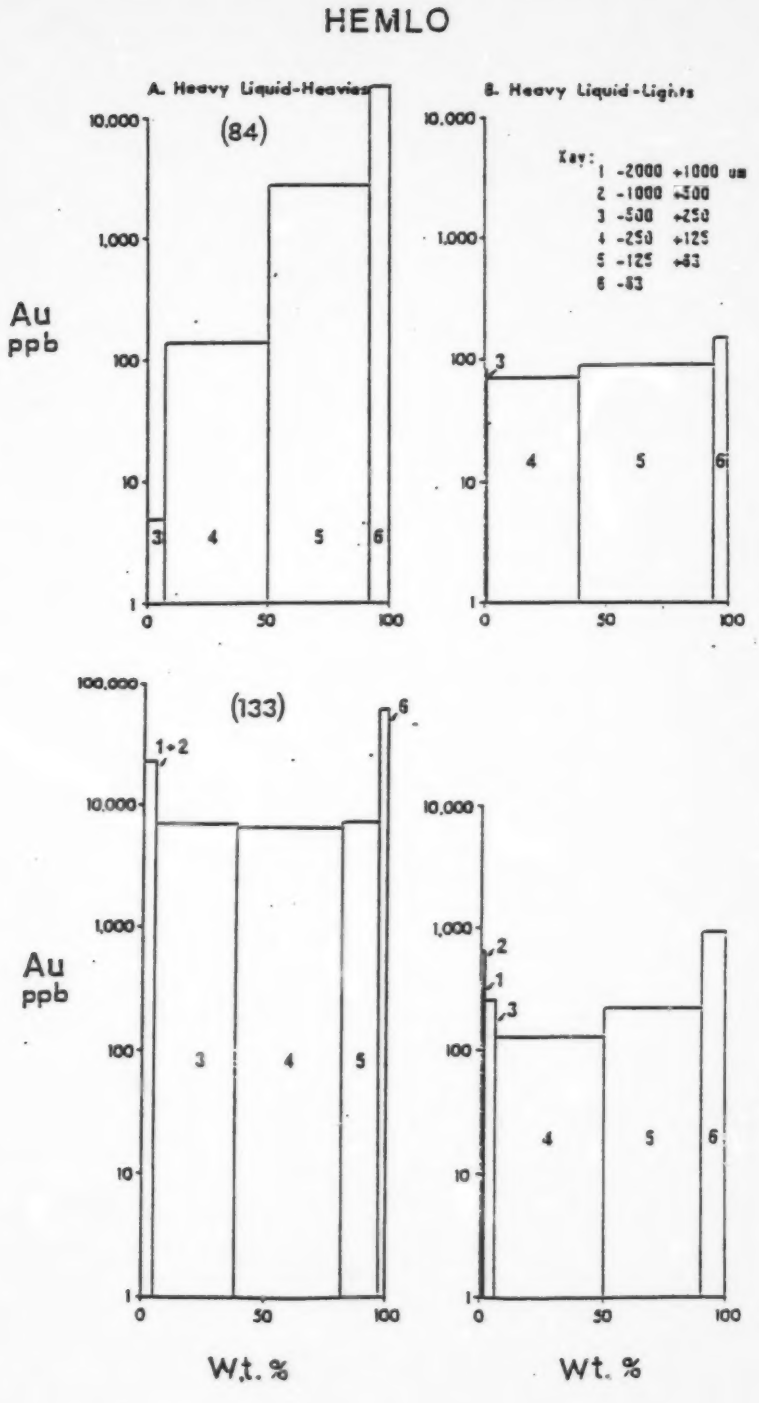


Figure E.1 A variation of the gold content with a particular size fraction in the heavy liquid-heavy and heavy liquid-light fractions of samples #84 and #133.

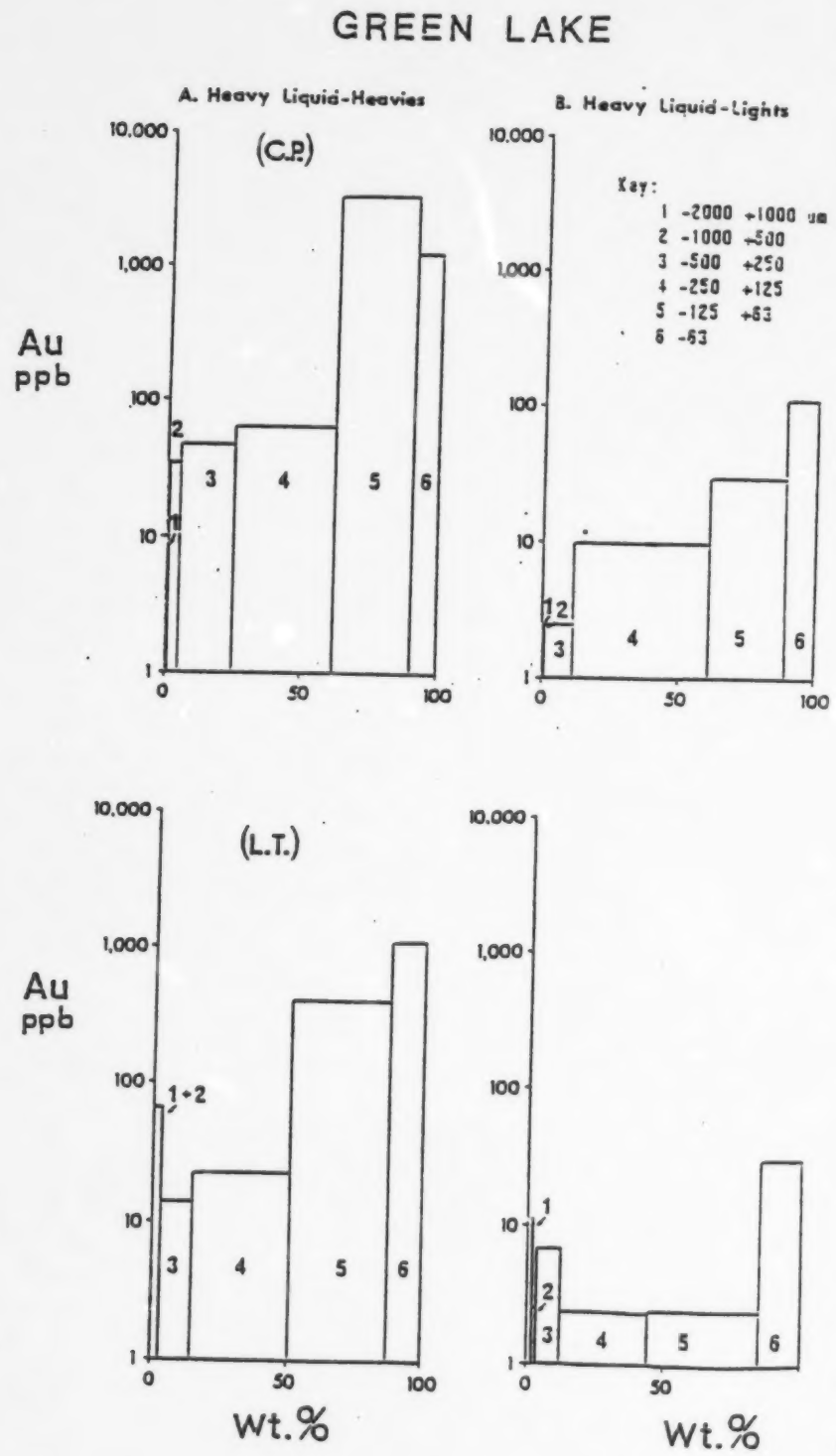


Figure E.2 A variation of the gold content with a particular size fraction in the heavy liquid-heavy and heavy liquid-light fractions of samples #CP and #LT.

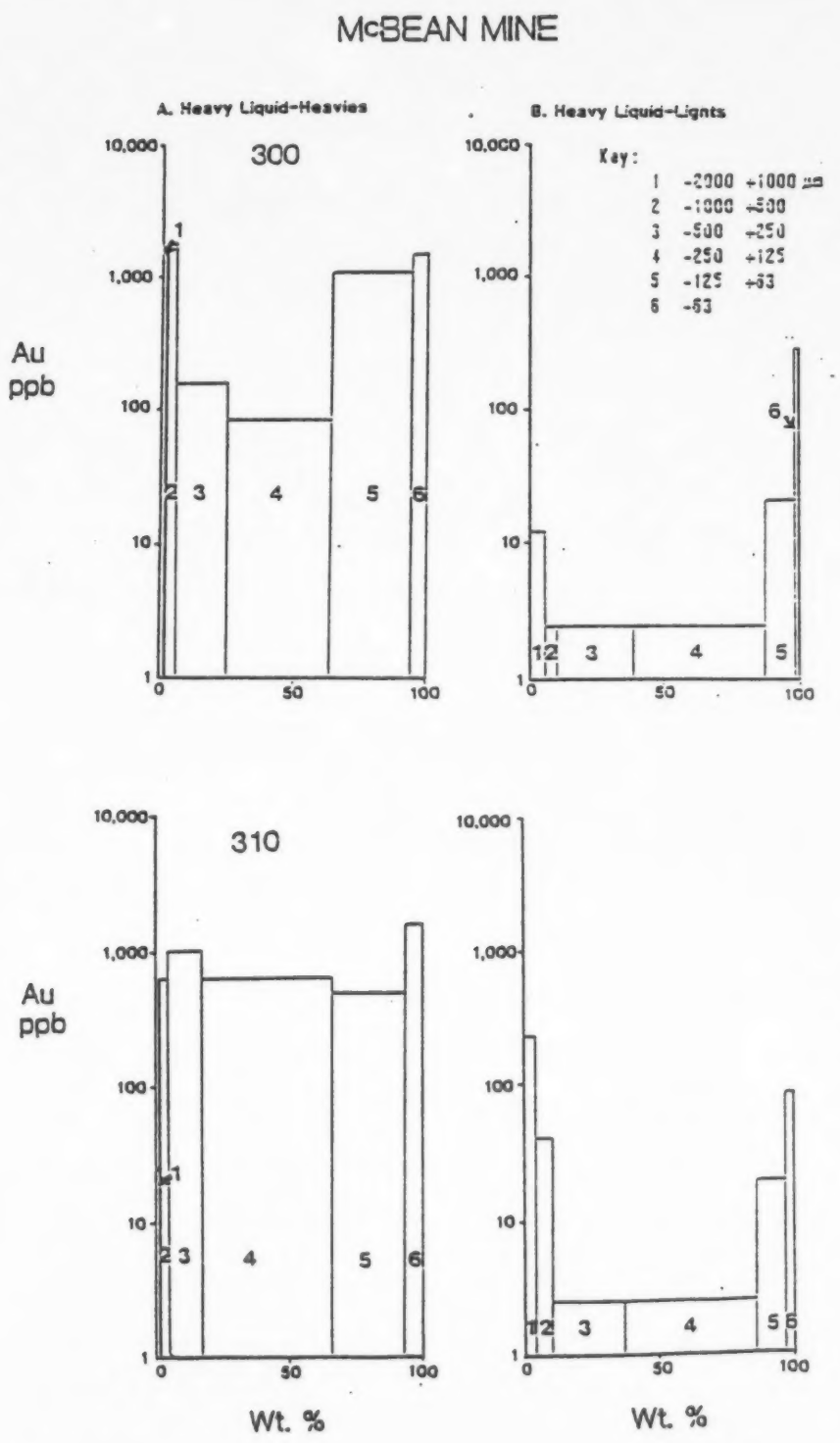


Figure E.3 A variation of the gold content with a particular size fraction in the heavy liquid-heavy and heavy liquid-light fractions of samples #300 and #310.

APPENDIX F

TRAVERSES OVER THE HEMLO DEPOSIT

At Hemlo, two areas were sampled; the Golden Sceptre and the Teck-Corona properties. The humus,the Ae horizon, the B horizon and the C horizon (till) were sampled where present. The gold data shown are based of analysis of the minus 63 µm fraction of the inorganic soil horizons and on the minus 500 µm fraction of the humus.

F.1 GOLDEN SCEPTRE PROPERTY

Samples were collected along traverses; 12 W, 14 W and 20 W (Figure F.1 to 3). All three traverses crossed the mineralization and extend at least 300 meters both up-ice and down-ice of the deposit.

THe concentrations of gold are generally higher in the B and C horizon samples than in the samples taken from the Ae horizon and the humus. The Ae horizon is not considered a useful sample type for geochemical exploration since metals are leached out of this horizon and are concentrated in the B horizon. The humus tends to give spot anomalies over mineralization while the inorganic horizons clearly identify mineralization and also give a dispersion train down-ice. Analysis of the minus 63 µm fraction of inorganic horizons best identifies mineralization by producing an exploration target much larger than the original. This improves the chances of detecting a

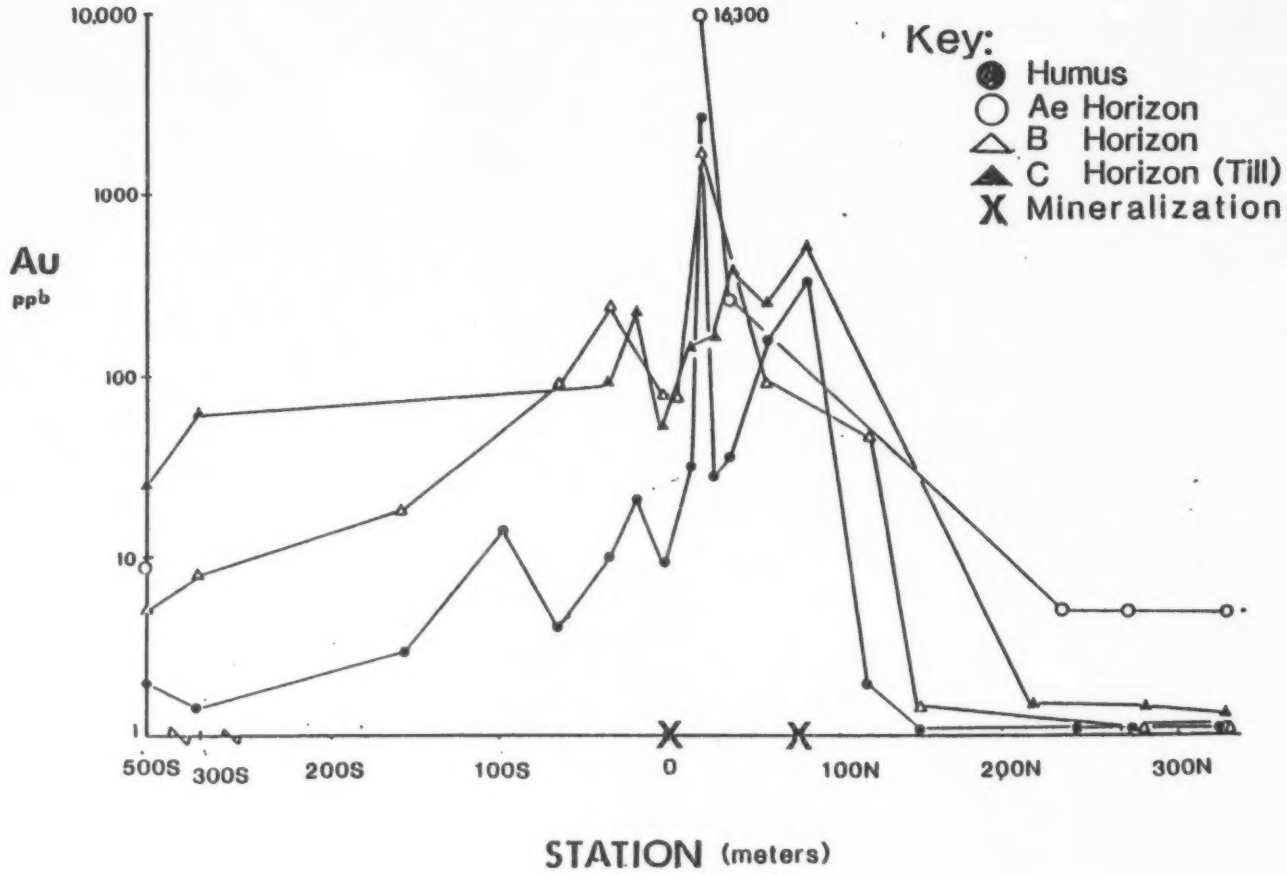


Figure F.1 Traverse 12 West, Golden Sceptre: Gold content of humus and various soil horizons.

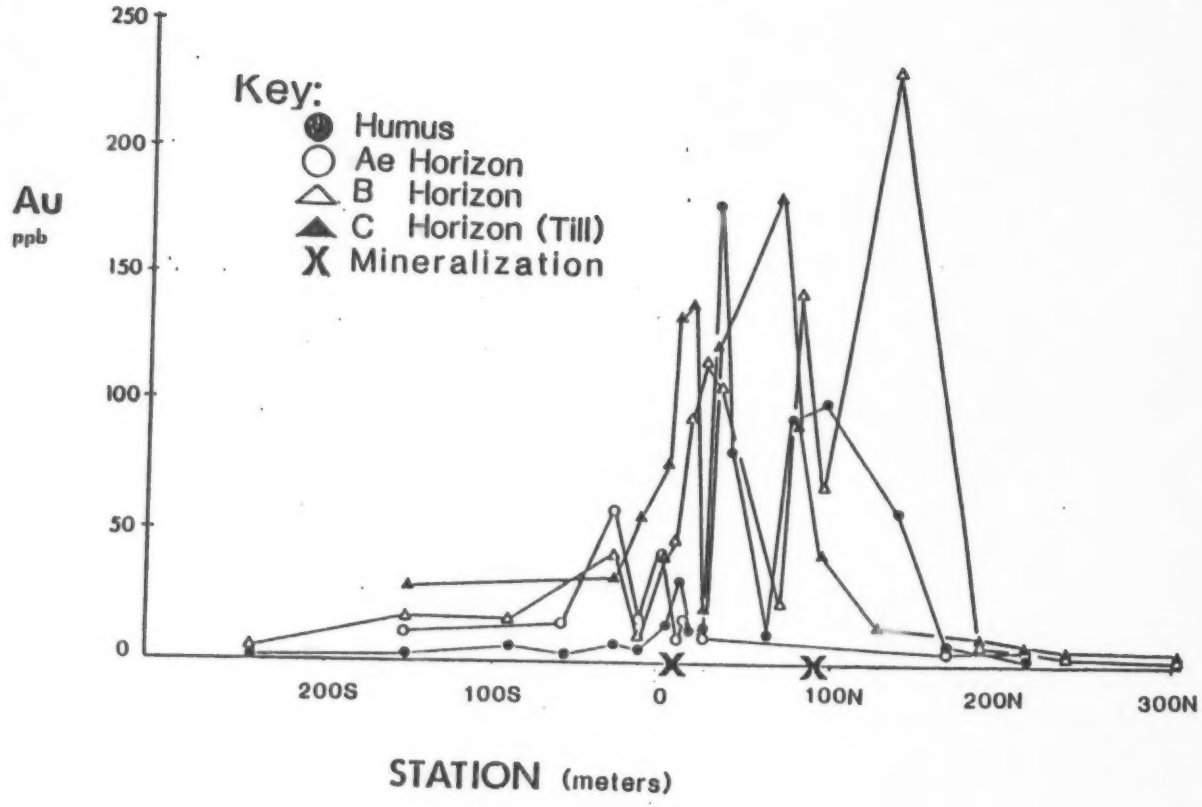


Figure F.2 Traverse 14 West, Golden Sceptre: Gold content of humus and various soil horizons.

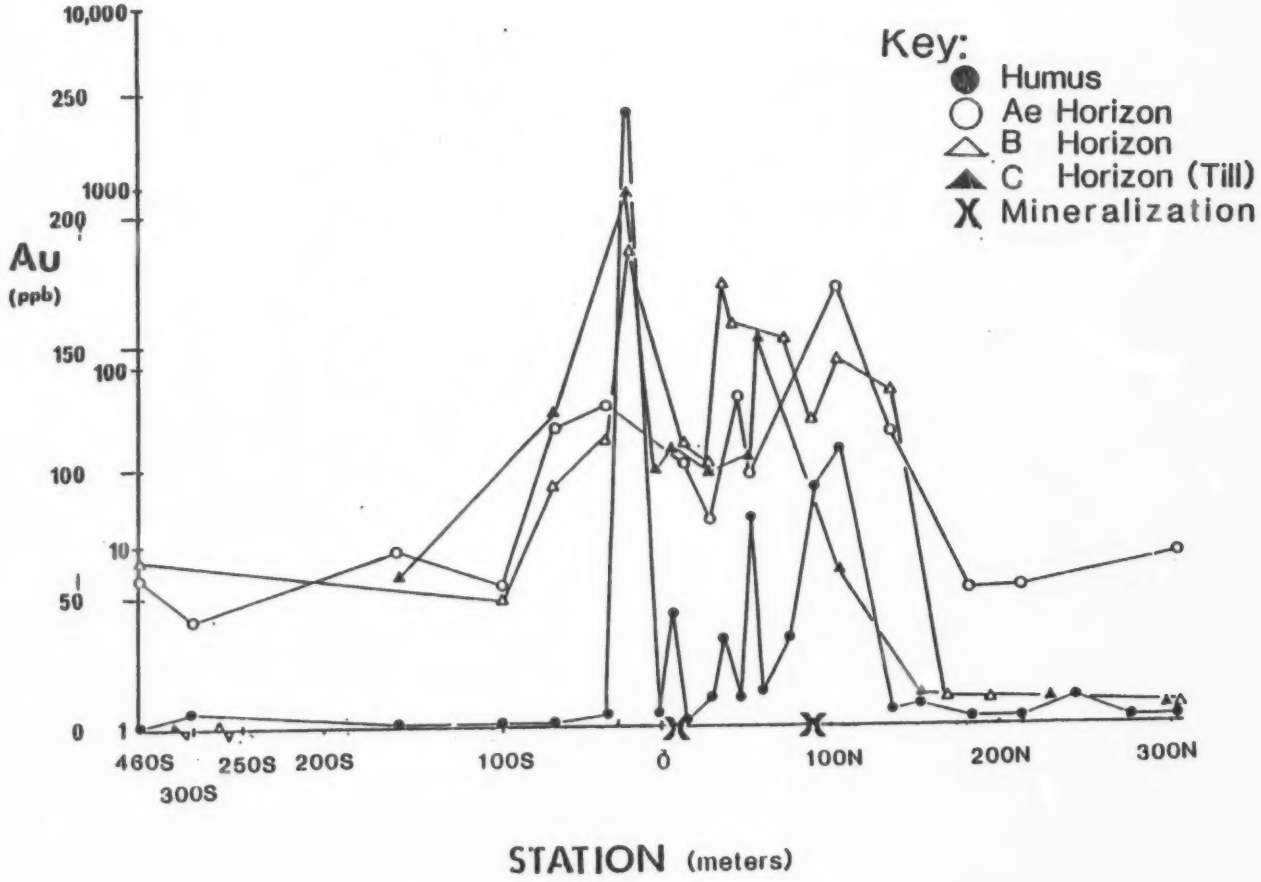


Figure F.3 Traverse 20 West, Golden Sceptre: Gold content of humus and various soil horizons.

deposit of this type. Humus may be useful in a follow-up geochemical sampling program. When sampling the B horizon it is important to ensure that this horizon is derived from the same parent material.

F.2 TECK-CORONA PROPERTY

Two traverses were sampled over the area of the main deposit, traverses 12 E and 34 E (Figures F.4 and 5). The material overlying bedrock is very shallow and therefore prevented a continuous sampling of the inorganic soil horizons. The gold concentrations in the B horizon and the till are much lower than those on the Golden Sceptre property. In this area, the semi-local till, that was sampled on the Golden Sceptre property, is underlain by an exotic till. Consequently, the B horizon in this area developed on this till and therefore the mineral composition of the B horizon does not reflect that of the underlying bedrock. Similarly, the mineralization was not eroded and incorporated into the semi-local till during that glacial advance.

Traverse, 16 W, is over a transported anomaly just south of the Williams claims (Figure F.6). The till was lodged into the stoss side of a bedrock high. The anomaly is clearly identified by all sample media.

Finally, a trench located at the western extension of the deposit was sampled. Analysis of the B horizon and the till horizon identify mineralization but the overburden immediately down-ice had been disturbed and therefore was not sampled.

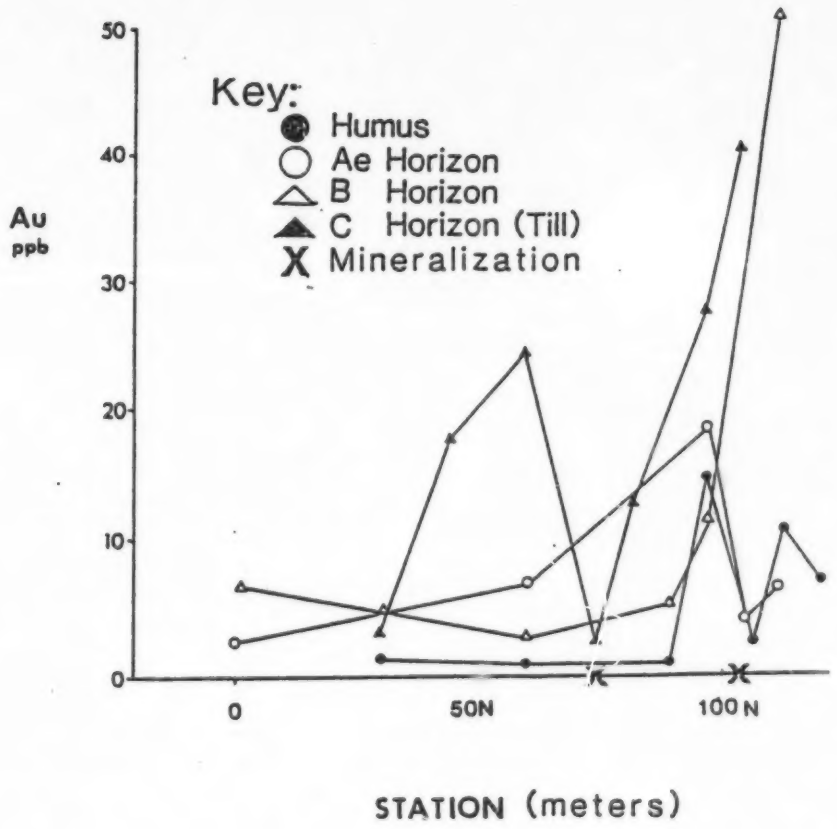


Figure F.4 Traverse 12 East, Teck: Gold content of humus and various soil horizons.

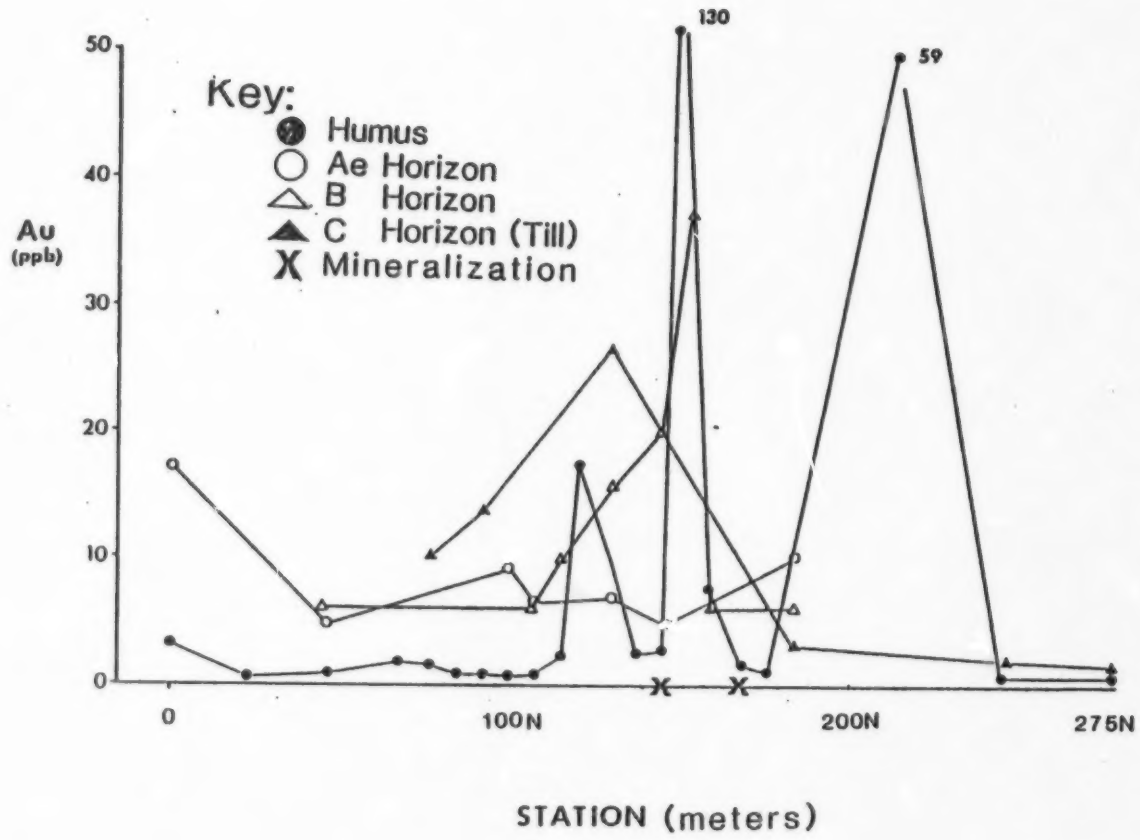


Figure F.5 Traverse 34 East, Teck: Gold content of humus and various soil horizons.

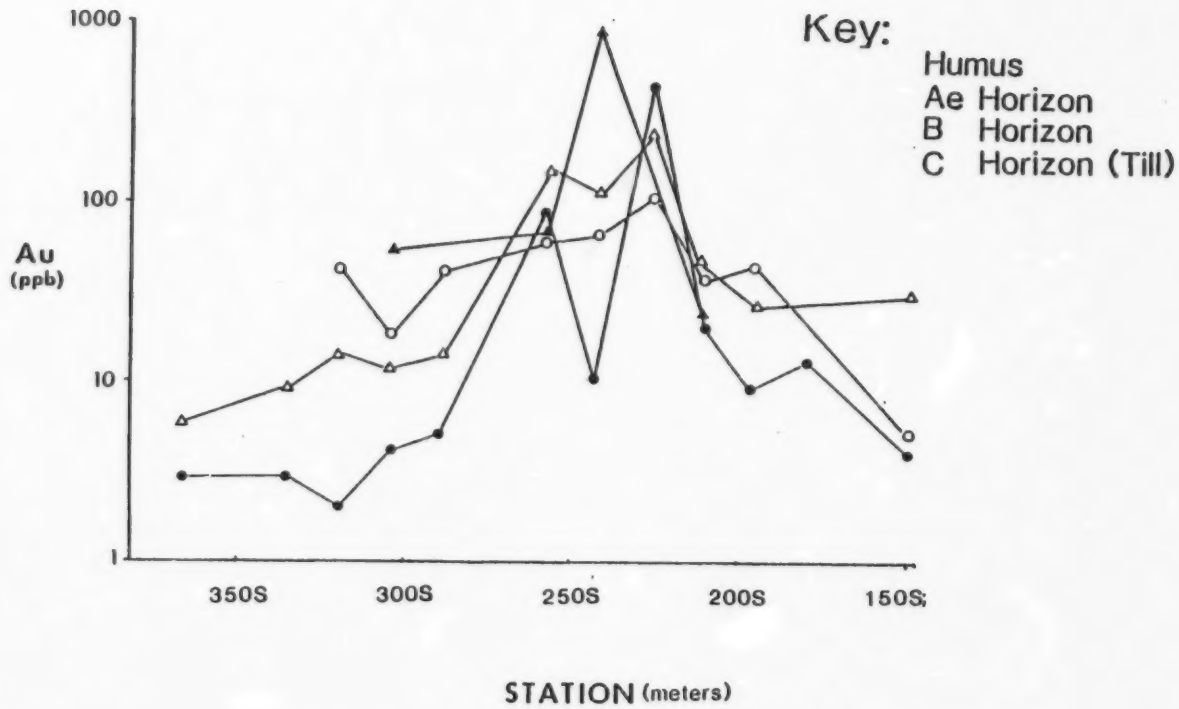


Figure F.6 Traverse 16 West, Teck: Gold content of humus and various soil horizons.

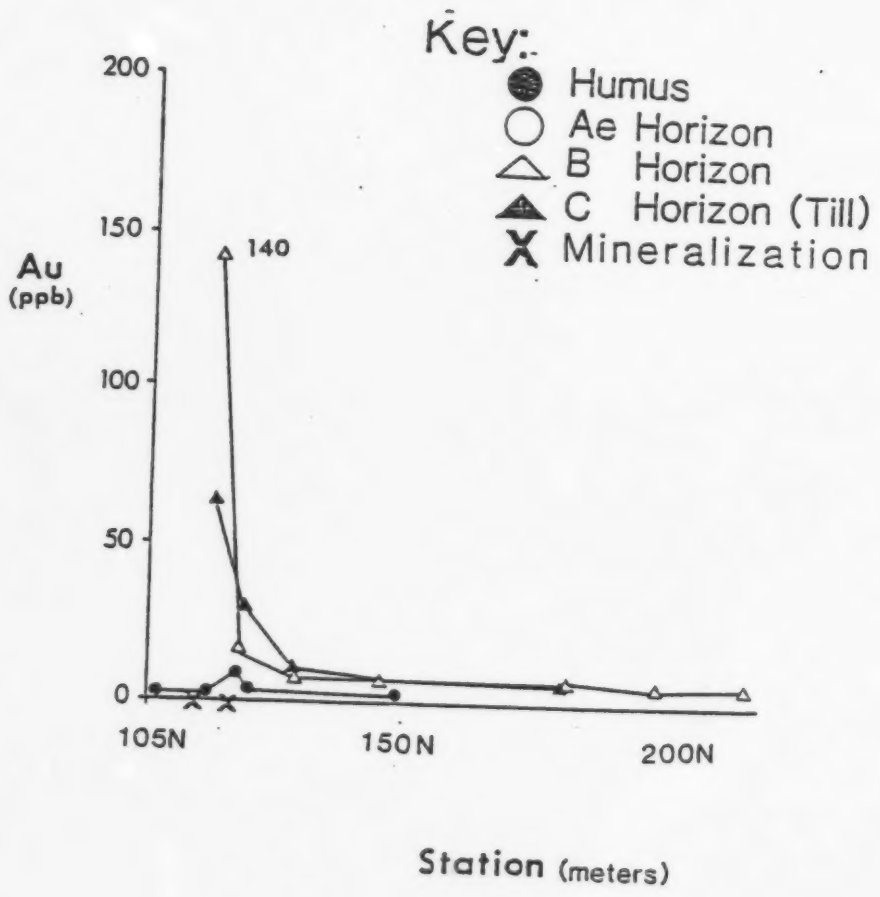


Figure F.7 Traverse, Teck trench: Gold content of humus and various soil horizons.

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